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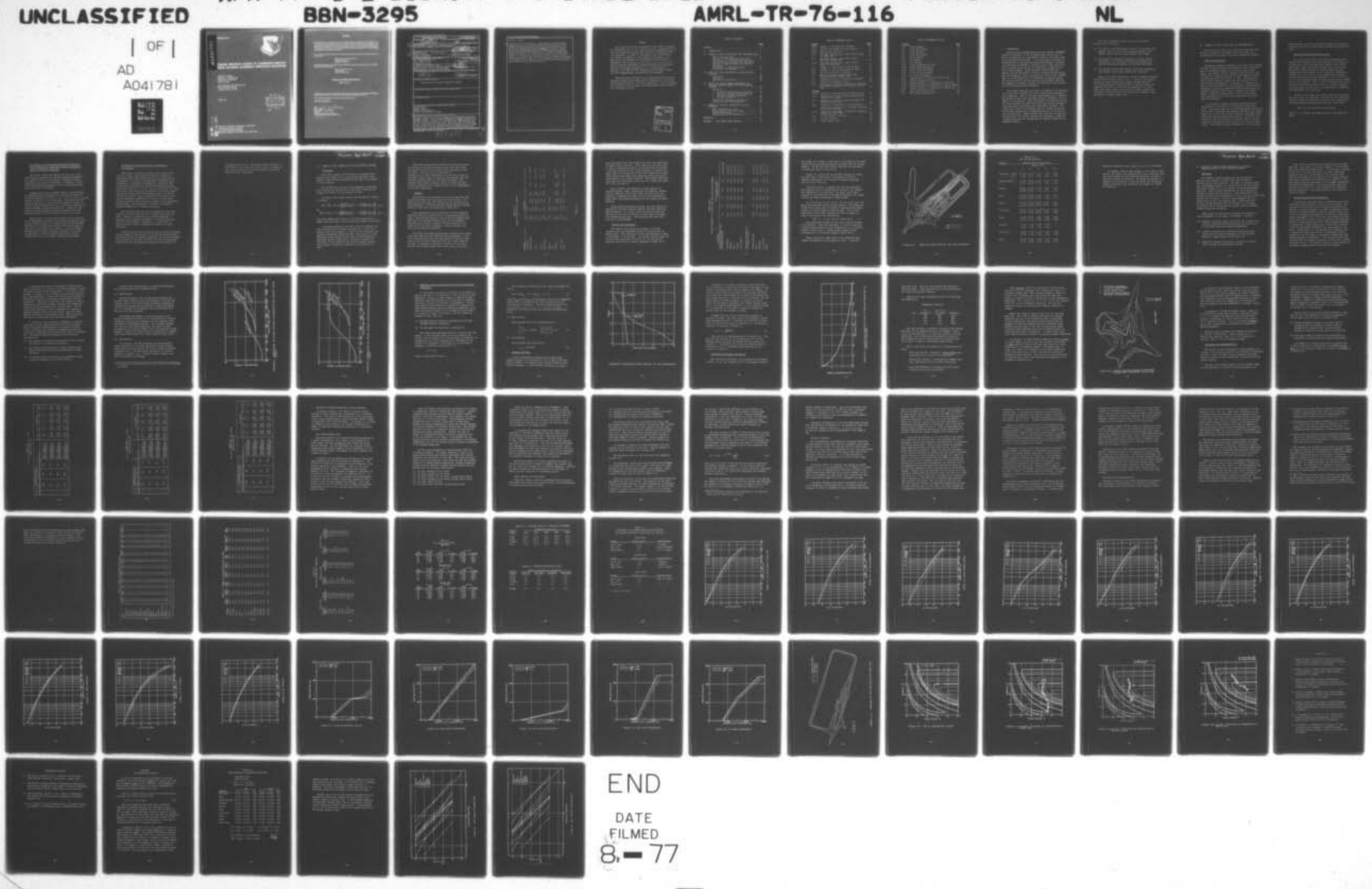

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FURTHER SENSITIVITY STUDIES OF COMMUNITY-AIRCRAFT NOISE EXPOSURE (NOISEMAP) PREDICTION PROCEDURE

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Henning E. von Gierke

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This report describes the results of studies of the sensitivity of the noise exposure contours to various model parameters and assumptions presently in the NOISEMAP procedure. The areas within Day/Night Level (L_{DN}) contours for ten Air Force airbases increased by 11 to 40 percent when the noise measure was adjusted for the presence of pure tones. The contour areas for typical mixed fighter, bomber/tanker, and training airbases were reduced by 3 to 11 percent by substitution of the SAE algorithms for ground-to-ground propagation and transition models, whereas adding the fuselage shielding algorithm reduced the next page

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Block 20. Abstract

contour areas by 13 to 22 percent. Since there is little firm evidence showing one set of algorithms more accurate than the other, the present NOISEMAP models will be retained until further technical analyses or new data show a clear basis for alteration. The contour areas for typical National Guard and combined bomber/tanker/fighter airbases for standard day weather conditions were reduced by up to 10 percent using summer-type climate conditions, but were reduced by 18 to 60 percent by winter weather conditions. Although use of standard day conditions results in contours that are quite representative for most bases, it is recommended that contours be developed based on a simple review of the absorption coefficients (for the 1000 Hz one-third octave frequency band) determined from the set of monthly average temperatures and relative humidities.

PREFACE

The sensitivity studies described in this report represent an intermediate step in the on-going technical assessment of the Air Force Community-Aircraft Noise Exposure (NOISEMAP) prediction procedure. A number of individuals have contributed to the studies in addition to the authors of the report. In particular, the guidance of the technical monitor, Jerry D. Speakman of the Biodynamics and Bionics Division, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio and the helpful assistance of Lt. Colonel Emmett W. Muenker of the USAF Air Base Planning and Development Branch, Air Force Headquarters, are gratefully acknowledged.

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I. INTRODUCTION

The Air Force community-aircraft noise exposure (NOISEMAP) prediction procedure [1-6] is the methodology used by the Air Force for assessing the environmental impact of aircraft noise in the vicinity of air bases. It is also used to evaluate the acceptability of new propulsion system developments, determining suppressor requirements, siting of new or noisy facilities and as a planning aid in the Air Installation Compatible Use Zone (AICUZ) program. Major decisions involved with new weapons systems developments, facility siting, aircraft assignment and compatible land use planning are based on this program. Thus, it is essential that the procedures be accurate within the current state-of-the-art and that the technical basis for the program be reviewed, assessed, and improved as new information and techniques become available.

This report describes the result of studies of the sensitivity of the noise exposure contours to various model parameters and assumptions. Some of the modeling assumptions are engineering decisions based upon existing technical information that is known to be incomplete. Other assumptions and weighting factors for noise exposure are based upon relatively sparse information based upon past sociological and psychological studies. The sensitivity studies are primarily directed towards seeing what effect these assumptions or weightings may have in the *size* of the noise contours. These analyses will then aid in establishing priorities for further research and development studies or in formulating specific recommendations towards changes in the NOISEMAP program.

The three sensitivity areas covered in this report consist of the following:

(a) The effect of tone adjustments applied to the noise level measure (use of a tone corrected sound exposure level (SELT), rather than the sound exposure level (SEL).

(b) The effects of alternate algorithms for excess ground attenuation, the transition between air-to-ground and ground-to-ground propagation, and airframe shielding.

(c) The effects of utilizing seasonal values for temperature and humidity rather than standard day conditions.

Each of the three studies are covered in separate sections of the report (Sections III, IV and V). Each of the studies extend the initial sensitivity studies reported earlier.[7] The studies generally extend the depth of earlier studies by comparing the effect of the various parameters on the day-night level (DNL) contours for entire air bases, rather than the study of limited sections of contours (for example, those produced by a single flight path).

II. SUMMARY OF STUDY CONCLUSIONS AND RECOMMENDATIONS

This section includes a brief technical discussion and provides a summary of the major study conclusions and recommendations from each of the three sensitivity studies.

Basic Study Approach

The general technical approach in the sensitivity studies has been to vary the particular parameter under study and to note the resulting change in noise contour area and/or shape. The initial studies[7] typically utilized noise level contours for individual aircraft or noise exposure contour for selected flight paths at an air base. This approach often yielded detailed insight into the influence of the factor under investigation. For example, a comparison of the noise level contours for single aircraft using different propagation algorithms permitted thorough identification of changes in general contour shape. However, the overall impact of parameter variations in terms of the complete noise exposure contours for entire operational air bases were not determined.

In the current studies, alternate algorithm factors were applied in calculation of contours for entire air bases. The studies made use of already-assembled operational and aircraft information and computer data decks for specific bases, and the fact that initial "baseline" day/night level (DNL) contours had already been computed. For most of the situations, DNL contours were not actually drawn, instead, areas were computed from the calculated DNL values at grid points. This permitted direct comparison of contour areas,

and eliminated costs for the actual drawing of the contours, except for the several cases shown as examples throughout the report.

Effects of Tone Corrected Noise Data

For ten Air Force bases, the areas of day/night level contours were compared using sound exposure level (SEL) and, alternatively, tone corrected sound exposure level (SELT) noise data. With tone corrected noise data, the air base DNL contours area increased by average amounts per base ranging from eleven percent to forty percent, depending on aircraft mix. For the five bases studied which operated aircraft having strong tone components (C-135B, B-52H, C-141 and C-5), the average increase in contour area per base ranged from 20 to 40 percent. Thus, it can be concluded that use of tone corrected noise data will result in sizable increases in contour area, with at least an eleven percent increase in area regardless of aircraft mix.

As part of the study, the contour areas were correlated with DNL values for each base. The slope of the correlation lines was relative constant from base to base, yielding the following expression relating contour area to DNL value:

$$DNL = a + 15.4 \log (DNL\ contour\ area)$$

where a is a constant that varies with the individual air base.

The Effects of Alternate Algorithms For Ground-to-Ground Propagation, Transitions Between Propagation Modes, and Aircraft Shielding

DNL contour areas were computed for three air bases utilizing SAE algorithms for ground-to-ground propagation, the transition between air-to-ground to ground-to-ground propagation, and aircraft shielding. In addition, contour areas were determined assuming only an air-to-ground propagation mode and no shielding.

Changing from current NOISEMAP (BBN) to SAE algorithms for ground-to-ground propagation and transition results in relatively moderate reductions in area (order of three to eleven percent for DNL 65 to 75 dB contours). The addition of SAE shielding algorithm to the other SAE algorithms results in sizable total area reductions (13 to 22 percent) compared to current NOISEMAP propagation algorithms. Compared to computations ignoring ground-to-ground propagation, the SAE algorithms result in area reductions of 25 to 45 percent.

Because there is little firm evidence to show that one set of propagation transition or shielding algorithms is more accurate than the other, we recommend that current NOISEMAP algorithms be retained until further technical analyses or data show a clear basis for alteration. We also strongly recommend that technical analyses, including field tests, be undertaken to develop improved algorithms or better substantiate the use of current propagation algorithms.

The Effects of Seasonal Values of Temperature and Humidity

From review of monthly temperature and humidity data for 23 air bases, three bases for which the product of temperature times relative humidity was less than 2000 for three months of the year were selected for detailed study. In addition to contours for standard day conditions, DNL contours were calculated for the months having the maximum and minimum product of T x R.H. For the low values of T x R.H. which occur only during the cold months of the year, sizable reductions in areas were found (ranging from 26 to 60% for the DNL 65 contour). From correlation of area ratios with the air absorption coefficient at 1000 Hz, a first order equation relating contour area with changes in air absorption was developed. This expression is useful in estimating possible changes due to climatic conditions.

The study confirms that use of standard day conditions results in contours that are quite representative for most bases. However, considering the potential advantage of increased local community acceptance to contours based upon actual air base climatic conditions, it is desirable to develop contours using an appropriate average of climatic conditions.

A simple procedure is recommended that involves determining the air absorption coefficient in the 1000 Hz one-third octave frequency band for the average temperature and relative humidity for each month of the year, and then selecting the absorption coefficient (and corresponding temperature and humidity) for

the sixth *lowest* value. This assures that there will be five months of the year with contours equal or larger in size, and six months with contours equal or smaller in size, than those calculated.

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III. IMPACT OF TONE CORRECTIONS ON NOISE EXPOSURE CONTOURS

Discussion

This study examines the difference in predicted noise exposure that results when tone corrected day-night level (DNLT) is used instead of day-night level (DNL) as a measure of noise exposure.

DNL and DNLT are closely related measures of cumulative noise exposure and differ only in that DNLT contains an adjustment to account for the presence of tones.

For single event noise sources, DNL and DNLT are defined as follows:

$$DNL = SEL + 10 \log \left[\begin{pmatrix} \text{number of} \\ \text{day events} \end{pmatrix} + 10 \begin{pmatrix} \text{number of} \\ \text{night events} \end{pmatrix} \right] - 49.4$$

and

$$DNLT = SELT + 10 \log \left[\begin{pmatrix} \text{number of} \\ \text{day events} \end{pmatrix} + 10 \begin{pmatrix} \text{number of} \\ \text{night events} \end{pmatrix} \right] - 49.4$$

where SEL (single event level) is the noise exposure for a single event and SELT is the tone corrected single event level.

In deciding whether to use DNLT or DNL as a measure for land planning one must answer two questions. First, can a person's subjective response to noise be more accurately predicted by using DNLT rather than DNL? This question is not addressed in this report but has been reviewed previously.[2] The second question that must be answered is whether the difference in the predicted DNLT and DNL exposure areas is large enough to justify the added cost and complexity of DNLT.

This study quantifies the effect of the tone correction by showing the calculated exposure areas that result when DNL and DNLT are used to describe actual operations at ten air bases. Previous work[7] to determine the influence of the tone corrections on noise contours was not conclusive since changes in exposure were computed only for selected operations and not for entire airfields. The current study examines exposure areas for entire air bases and thus provides a more complete picture of the significance of the tone corrections.

Analysis

To determine the importance of the tone correction, DNL and DNLT exposures were calculated for ten air bases. All operations at each base were included in the calculation of total exposures. The bases that were chosen and the aircraft present at each base are summarized in Table III-1.

Data availability and the presence of certain aircraft types were the main considerations in choosing airfields for study. Baseline DNL exposure areas as well as NOISEMAP input data had to be available before a base could be examined. These data were readily available for many airfields as a result of the Air Force's program to prepare baseline contours for all military airfields.

The second consideration was whether aircraft with strong tones were present at the airfields being considered. A previous study has shown that the noise spectra of most jet aircraft in the Air Force inventory result in a tone correction of about 1.3 decibels at 1000 feet. However, of the major aircraft types, which number about forty, there are several

TABLE III-1

SUMMARY OF AIRFIELDS AND AIRCRAFT

AIRFIELD	AIRCRAFT						
Charleston	C-141	B-727					
Seymour-Johnson	B-52G	C-5	C-141	C-9	C-135	F-4	F-105
	T-38	T-39	F-111	A-7			
Minot	K-135	B-52H	C-141	T-39	B-57	F-106	T-33
	C-9	A-4	F-101	F-5			
Travis	C-141	C-5	K-135	C-9	A-7	F-101	
Grand Forks	B-52H	C-135	C-141	F-101	A-4	T-38	T-39
	C-9						
McGuire	C-141	F-105	C-135A				
Vance	T-37	T-38					
Whiteman	T-37	T-38	T-33	F-4	F-14	F-100	A-4
	T-39	C-9	K-135	C-141	B-52H	C-130	
Little Rock	C-130	F-101	K-135				
Eglin	F-4	C-141	C-130	F-111	T-39	T-38	C-9
	A-7						

TABLE III-1

with high bypass ratio fan engines that have tone corrections of greater than 3 decibels. Since almost any air base could be used to represent operations of aircraft with the nominal 1.3 decibel correction, this study attempted to quantify the upper limit on the influence of the tone corrections by examining several bases where tone producing aircraft are major contributors to the overall exposure. The aircraft that have large tones in their noise spectra are the C-135B, the B-52H, the C-141, and the C-5.

These aircraft are significant noise producers at Charleston, Minot, Travis, Grand Forks, and McGuire. Seymour-Johnson, Whiteman, Little Rock, Eglin and Vance were also examined to determine the impact of the tone correction at bases where tone producing aircraft do not control the noise exposure.

Having chosen airfields for study, the next step was to recalculate the noise exposure areas at each base using the DNLT descriptor. To do this, SELT and ALT noise data were inserted in the place of SEL and AL noise data in the baseline NOISEMAP input decks. DNLT exposure areas were then calculated using NOISEMAP.

Results and Conclusions

The measure used to assess the impact of the tone correction was the difference between the DNL and DNLT exposure areas. This difference in area was expressed in terms of percentage of the DNL area. The percent of area change for each base was calculated for the 65, 70, 75, 80, and 85 exposure levels with the results tabulated in Table III-2.

TABLE III-2

PERCENT INCREASE IN CONTOUR AREA WITH DNLT NOISE MEASURE

AIRFIELD	Percent Area Change in Exposure Level					
Airfields with Many Tone Producing Aircraft	65	70	75	80	85	Avg./Std.Dev.
Charleston	34.0	53.4	31.4	26.6	31.4	35.4/10.4
McGuire	25.5	25.9	27.0	27.8	31.4	27.5/ 2.3
Minot	40.4	61.4	22.7	33.3	42.7	40.1/14.2
Travis	16.9	30.2	30.3	22.7	35.0	27.1/ 7.2
Grand Forks	15.5	18.7	18.5	24.0	28.9	21.1/ 5.3
Airfields with Few Tone Producing Aircraft						
Seymour-Johnson	13.3	9.4	11.4	14.7	13.3	12.4/ 2.0
Vance	8.9	10.7	11.1	11.2	14.3	11.2/ 1.9
Whiteman	18.1	24.0	13.8	36.5	-	23.1/ 9.9
Little Rock	16.1	14.6	14.5	11.4	10.7	13.4/ 2.3
Eglin	13.9	14.5	13.9	12.0	10.5	13.0/ 1.7

The average area change at each base is also shown in the table along with the standard deviations associated with the average changes. The DNL and DNLT exposure areas for the individual air bases are shown in Table III-3.

Figure III-1 shows the DNL and DNLT contours for Travis Air Force base. This figure is included to provide a graphic presentation of the change in exposure resulting from the tone correction.

From Table III-2, it appears that the tone correction will cause at least an eleven percent change in the exposure area regardless of aircraft mix. For bases whose noise exposure is controlled by tone producing aircraft, the change in area may range from twenty to forty percent.

In the Appendix of this report, the DNL values were compared with the areas within the DNL contours. The comparison of DNL level versus area is helpful in evaluating the significance of a given change in exposure area. The Appendix shows that for the bases examined, the DNL is roughly related to the area by the relationship.

$$DNL = a - 15 \log (\text{area in square miles}) \quad (1)$$

This relationship holds for DNL levels from 65 decibels to 85 decibels. From this expression, it can be shown that a twenty percent change in area corresponds to a 1.2 decibel change in noise level. A fifty percent change in area corresponds to a 2.6 decibel change in noise level.

These calculations imply that a tone correction which changes the exposure area by twenty to fifty percent will

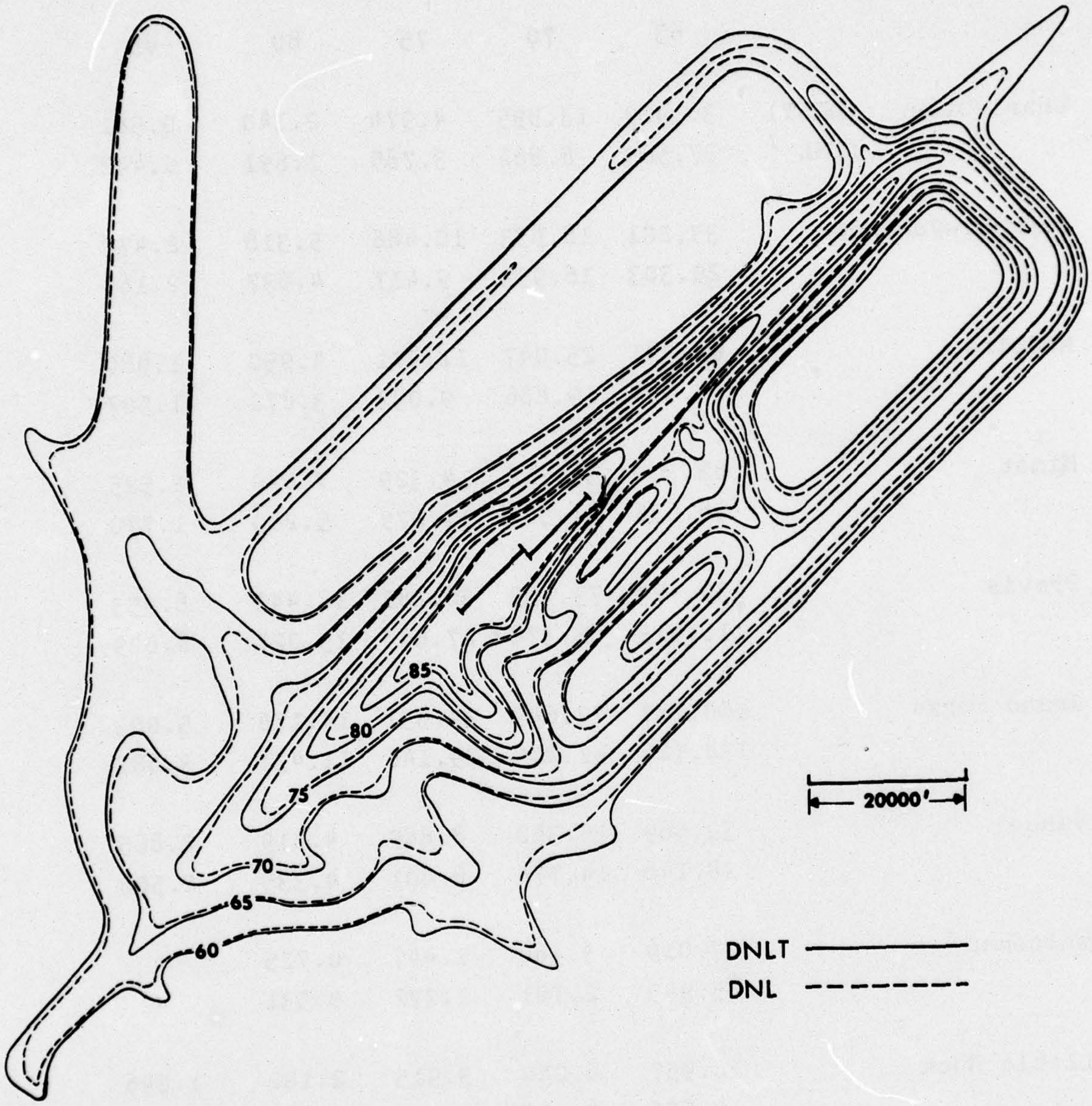

FIGURE III-1. TRAVIS AIR FORCE BASE DNL AND DNLT CONTOURS

TABLE III-3

DNLT AND DNL EXPOSURE

AIRFIELD		EXPOSURE AREAS (SQUARE MILES)				
		Exposure Level				
		65	70	75	80	85
Charleston	(DNLT)	36.929	13.595	4.974	2.140	0.581
	(DNL)	27.563	8.862	3.785	1.691	0.442
Seymour-Johnson		33.201	18.533	10.486	5.318	2.473
		29.303	16.933	9.417	4.637	2.163
McGuire		60.331	25.047	11.471	4.950	1.980
		48.054	19.886	9.032	3.872	1.507
Minot		82.300	34.713	14.329	7.040	2.525
		58.636	21.503	11.679	5.280	1.770
Travis		130.424	73.433	36.281	18.442	8.953
		111.513	56.378	27.845	15.027	6.629
Grand Forks		160.287	72.649	34.531	14.176	5.003
		138.726	61.209	29.146	11.431	3.881
Vance		30.669	16.352	8.889	4.819	2.865
		28.148	14.774	8.001	4.335	2.506
Whiteman		7.019	3.460	1.447	0.725	-
		5.945	2.791	1.272	0.531	-
Little Rock		16.957	8.080	3.915	2.102	1.246
		14.606	7.052	3.420	1.887	1.126
Eglin		34.395	16.472	8.190	4.154	2.334
		30.205	14.382	7.188	3.709	2.112

change the exposure at any location by 1.2 to 2.6 decibels.

In summary, sizeable area changes, on the order of forty percent, may result from implementing a tone correction, however, area changes of this magnitude represent a change in exposure of about two decibels. The graphs in Appendix A of exposure area versus DNL or DNLT are useful for estimating changes in exposure area resulting from changes in volumes of operations.

IV. EFFECTS OF EXCESS GROUND ATTENUATION AND FUSELAGE SHIELDING MODELS ON NOISE EXPOSURE CONTOURS

Discussion

The NOISEMAP computer program has been developed to generate noise exposure contours (DNL, CNEL or NEF) for military and civilian airfields. To create an airfield noisemap, the program requires (1) a description of aircraft flight and ground activity and (2) an aircraft noise and performance data base. Based on this information, the sound exposure is modeled at various ground locations. This sensitivity study extends work previously undertaken to[7] study alternative algorithms dealing with the manner in which sound propagates when the noise source is at or near ground level. Under these conditions, ground observers view the aircraft at a low angle of elevation above the horizon and special sound attenuating conditions must be recognized.

Three points are covered in this study with regards to sound propagation at low angles of elevation. They are:

(1) Methods of modeling excess attenuation due to ground reflection, absorption and barriers when the aircraft is on the ground (ground-to-ground propagation),

(2) methods of modeling the transition between ground-to-ground and air-to-ground propagation as the aircraft appears at higher angles of elevation, and

(3) methods of modeling sound source shielding by the aircraft fuselage for multi-engine aircraft.

Item 1 must be considered when generating the aircraft data base, while Items 2 and 3 are integral to the functioning of the computer program itself. In combination, a change in any or all of these algorithms can create significant differences in the size and shape of the computed noise contours, especially in the vicinity of the runway sideline. This report describes those differences in relation to the algorithms currently implemented in the NOISEMAP program and its data base preparation. Our previous study[7] dealt primarily with the effects of these algorithms on individual aircraft operations. This study focuses on the effects on entire air bases.

1. <u>Ground-to-Ground Sound Propagation</u>

The aircraft noise data base is comprised of two noise level (SEL) versus distance curves for each aircraft. One describes the noise level of an *airborne* sound source radiating to a ground observer; the other an *earthbound* sound source to a ground observer. They are commonly referred to as the "air-to-ground" propagation curve and the "ground-to-ground" propagation curve, the latter curve depicting lesser noise levels due to excess ground attenuation and shielding effects of intervening structures. Two alternative methods of generating a sound exposure level (SEL) versus distance curve for over-ground propagation are investigated in this study. These include (1) the BBN method[2,3] currently used to prepare the noise data base for the NOISEMAP computer program and (2) the Society of Automotive Engineering (SAE) method described in Reference 8. Both methods utilize data acquired under "in-flight" conditions to develop the "ground-to-ground" curves. They differ, however, in their method of applying over-ground excess attenuation adjustments.

To understand the method of applying the excess attenuation adjustments it is helpful to review the manner in which the "air-to-ground" curve is generated. In this case a line-of-sight is assumed to exist between the source and receiver. Thus, the attenuation of sound with distance can generally be attributed to spherical spreading (inverse square) and air absorption[9]. Under these conditions, raw flight test data is adjusted to a specified reference distance and standard day conditions on an individual frequency band basis. The adjusted noise spectrum is then "propagated" to a number of specific distances from the noise source. From the "propagated" spectrum the sound exposure level (SEL) is computed and curves of sound level versus distance determined.

In contrast to "air-to-ground" propagation, a line-of-sight may *not* exist when sound source as well as receiver are on the ground (depending upon the presence of intervening structures) and additional propagation losses may arise due to shielding, ground absorption, ground reflections, etc. The ground-to-ground propagation case is further confounded by:

(1) The tremendous variability encountered in size, spacing and location of intervening structures,

(2) the equally large variability in type of ground cover (and its associated reflective and absorptive characteristics)

(3) the minimal amount of empirical data available to make a critical evaluation of the above factors.

Despite these uncertainties, two simplified approaches have been proposed and are described below.

(a) BBN Procedure

The BBN procedure[3] uses the same basic technique and raw data used to generate the "air-to-ground" curve with the exception that (a) an excess ground attenuation spectrum is included when propagating the spectrum to various distances and (b) 5 decibels are subtracted from all SEL values once the curve has been computed.*

By applying adjustments to the noise *spectrum,* the absolute differences between the "air-to-ground" and "ground-to-ground" curves will be dependent upon the spectral characteristics of individual aircraft. As an example, Figures IV-1 and IV-2 show these differences (in terms of excess attenuation) for a typical fighter (F-4) and transport (B-52H) aircraft. Figure IV-1 denotes excess attenuation for takeoff noise levels while Figure IV-2 treats approach noise levels.

(b) SAE Procedure

In contrast to the BBN procedure, the SAE algorithm[8] simply subtracts an SEL excess attenuation versus distance curve from the "air-to-ground" SEL curve to obtain a "ground-to-ground" curve. The same excess attenuation is used regardless of aircraft type. Different curves, however, are used for takeoffs and landings.

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* *To account for terrain and the shielding effects of intervening structures.*

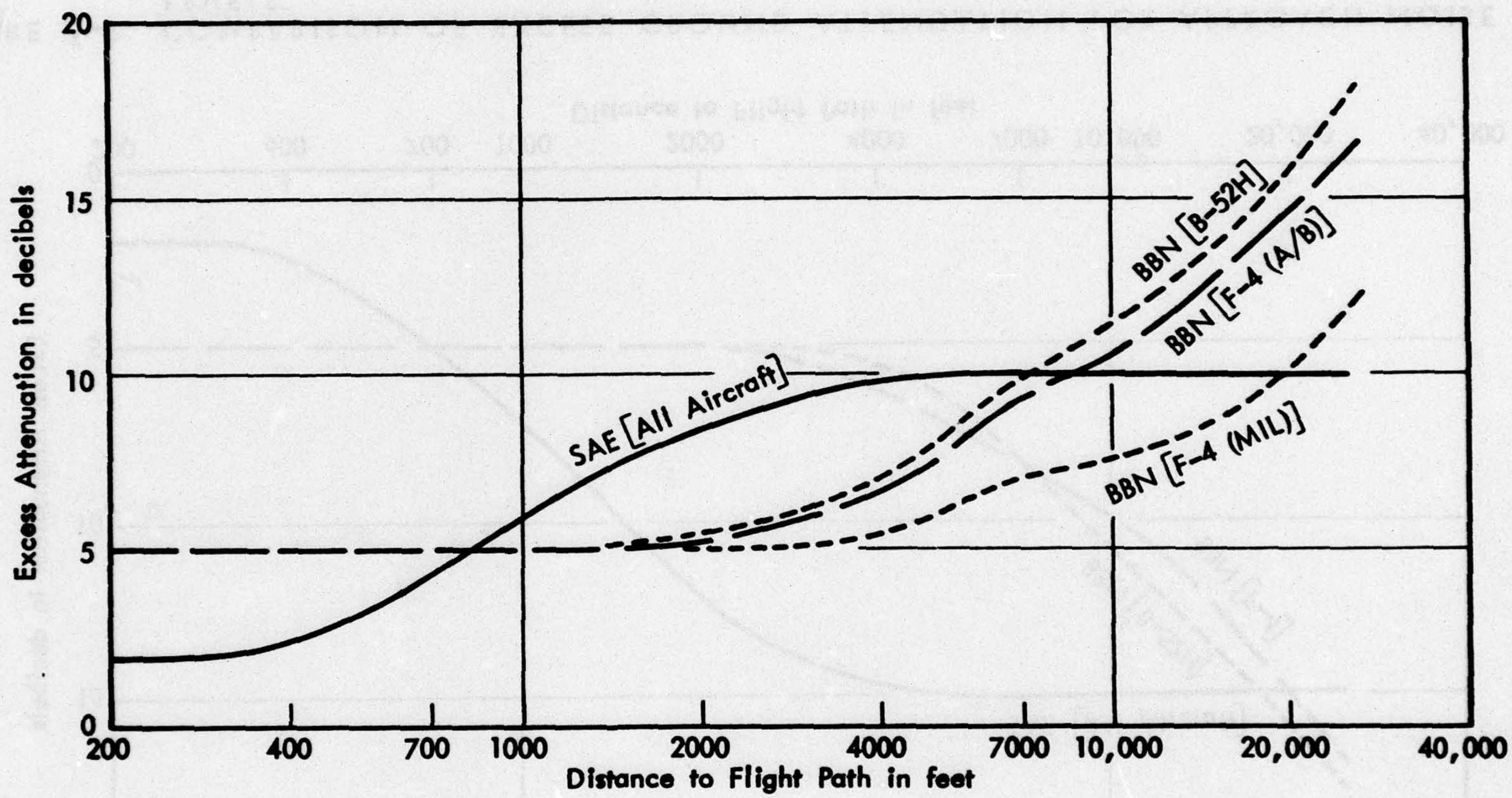

FIGURE IV-1. COMPARISON OF EXCESS GROUND ATTENUATION FOR TAKEOFF NOISE LEVELS

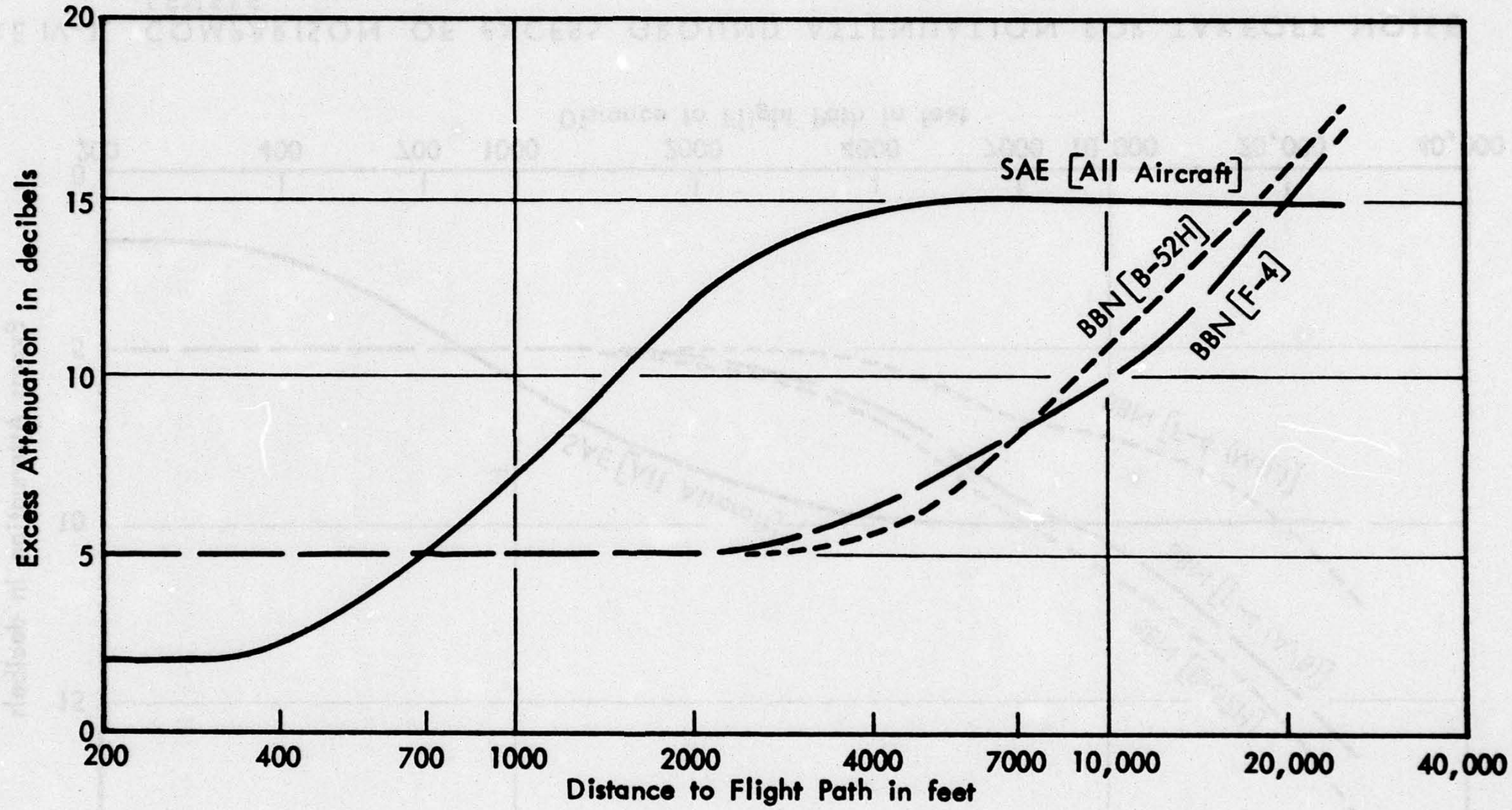

FIGURE IV-2. COMPARISON OF EXCESS GROUND ATTENUATION FOR APPROACH NOISE LEVELS

2. Transition Between Ground-to-Ground and Air-to-Ground Propagation

In cases where the aircraft is either on the ground or high in the air, it is clear which of the two curves is most applicable. However, at small angles of elevation (other than zero, when the aircraft is on the ground) a transition zone exists between the two modes of propagation. Several algorithms have been proposed to handle the transition between ground-to-ground and air-to-ground propagation, all of which interpolate between the two propagation curves based on a function of angle of elevation. The two algorithms examined in this study are:

(1) The BBN algorithm currently implemented in the USAF NOISEMAP computer program, and

(2) the SAE algorithm (described in Reference 8).

Both transition algorithms function in exactly the same manner. As the aircraft passes the ground observer the closest point of approach is noted and angle of elevation (β) between this point and the ground plane (subtended by the observer) is determined. This angle, β, is then used to determine a transition coefficient, T, by

$$T = f(\beta) \qquad (1)$$

where T varies between 0 and 1.

The transition coefficient is then used to determine the SEL by

$$SEL = SEL_{G-G} \cdot (T) + SEL_{A-G} \cdot (1 - T) \tag{2}$$

where SEL_{G-G} and SEL_{A-G} are determined from the two propagation curves based on the aircraft-to-observer distance at the closest point of approach. The only difference between the two procedures is the f (β). The functions are shown graphically in Figure IV-3 and are described mathematically below.

(a) BBN Procedure

This procedure uses the following function:

$$\begin{aligned} T &= 1 && \text{for } \beta \leq 4.3° \\ T &= 2.5 - 0.3491\beta && \text{for } 4.3° < \beta \; 7.2° \\ T &= 0 && \text{for } \beta \geq 7.2° \end{aligned} \tag{3}$$

(b) SAE Procedure

This procedure uses the function:

$$T = e^{-(\tan 3\beta)^{\frac{1}{2}}} \tag{4}$$

3. Fuselage Shielding

A third consideration (related only to some multi-engine aircraft) is the potential of one or more of the aircraft's engines to be *shielded* from a ground observer by the aircraft fuselage. A simple example illustrates the point.

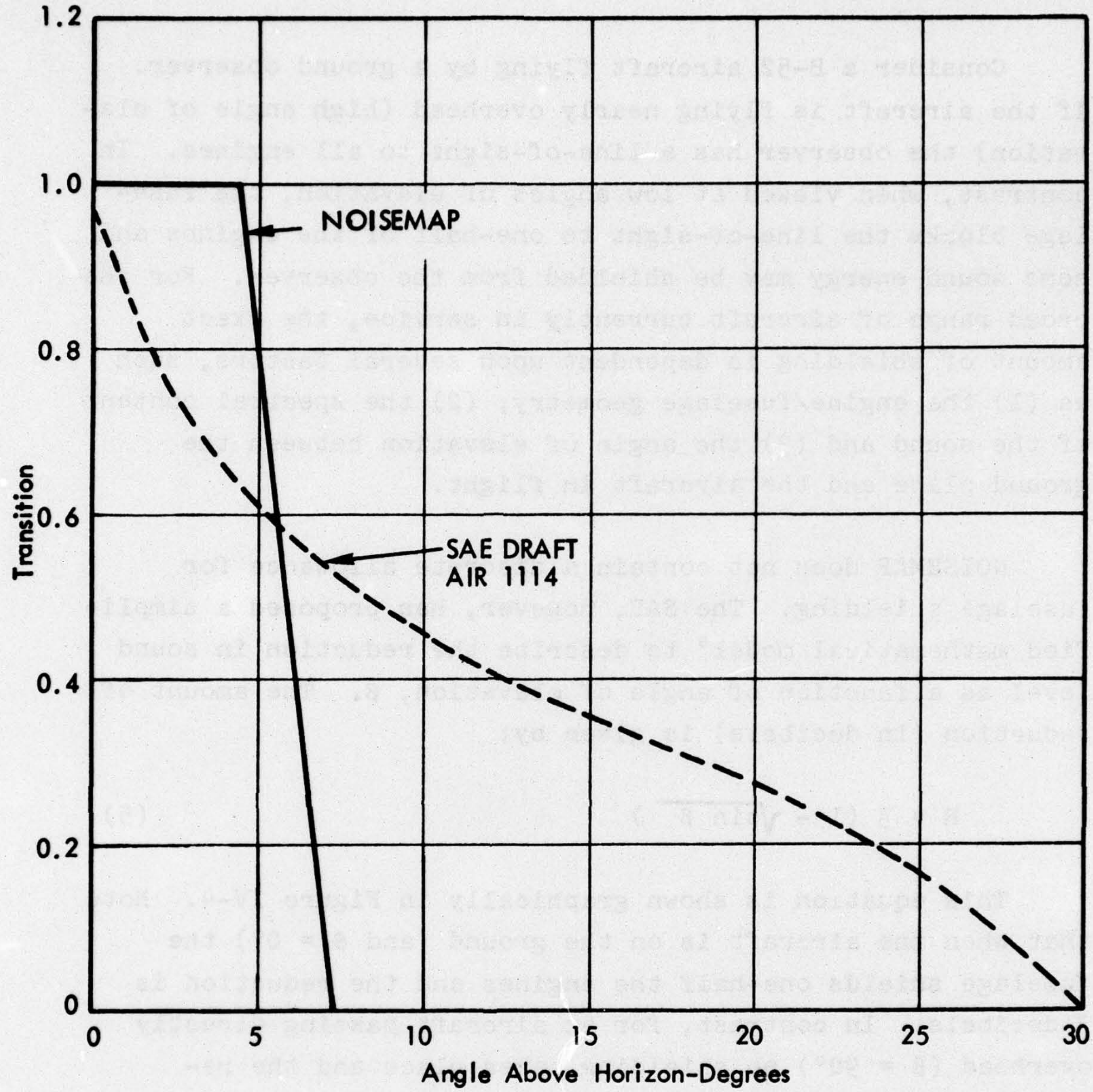

FIGURE IV-3. TRANSITION FROM GROUND TO AIR ATTENUATION

Consider a B-52 aircraft flying by a ground observer. If the aircraft is flying nearly overhead (high angle of elevation) the observer has a line-of-sight to all engines. In contrast, when viewed at low angles of elevation, the fuselage blocks the line-of-sight to one-half of the engines and some sound energy may be shielded from the observer. For the broad range of aircraft currently in service, the exact amount of shielding is dependent upon several factors, such as (1) the engine/fuselage geometry, (2) the spectral content of the sound and (3) the angle of elevation between the ground plane and the aircraft in flight.

NOISEMAP does not contain a discrete allowance for fuselage shielding. The SAE, however, has proposed a simplified mathematical model[8] to describe the reduction in sound level as a function of angle of elevation, β. The amount of reduction (in decibels) is given by:

$$R = 3\left(1 - \sqrt{\sin \beta}\right) \tag{5}$$

This equation is shown graphically in Figure IV-4. Note that when the aircraft is on the ground (and $\beta = 0°$) the fuselage shields one-half the engines and the reduction is 3 decibels. In contrast, for an aircraft passing directly overhead ($\beta = 90°$) no shielding takes place and the reduction is 0 decibels.

Sensitivity Assessment and Results

The sensitivity assessment was performed by considering a number of test case combinations of the propagation models

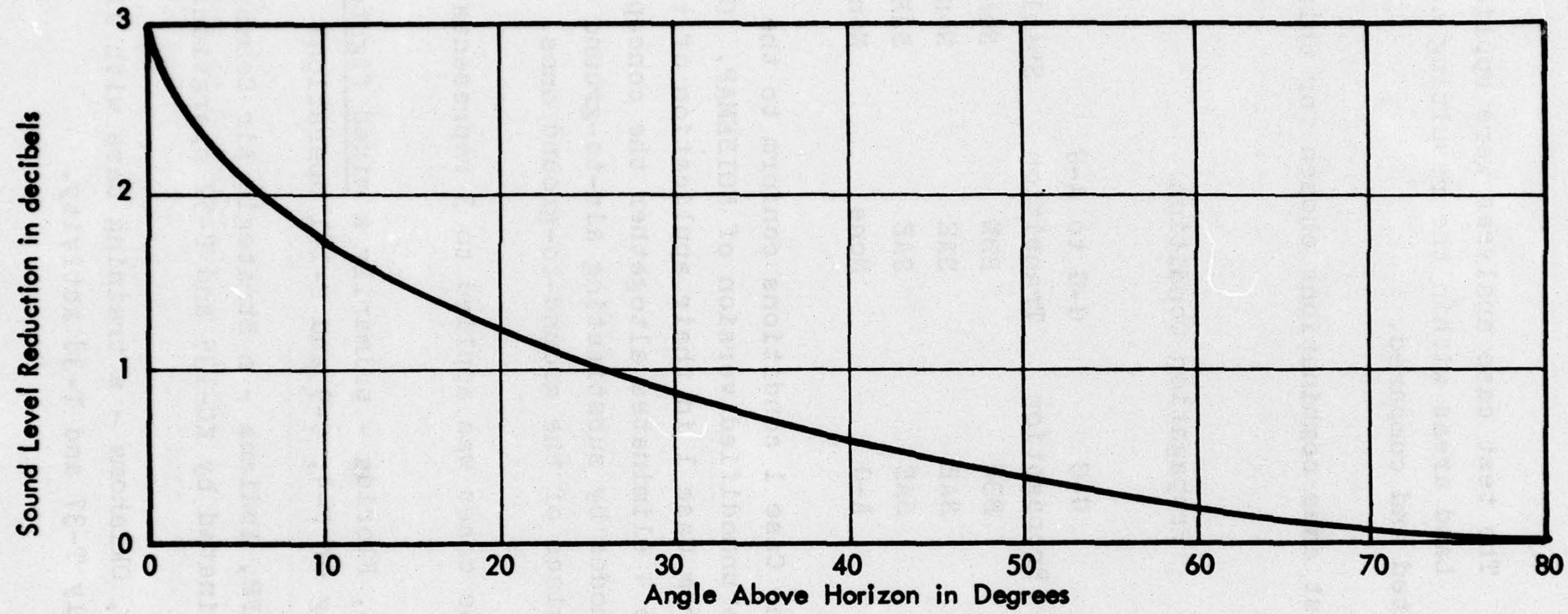

FIGURE IV-4. SOUND LEVEL REDUCTION DUE TO ENGINE SHIELDING BY AIRCRAFT FUSELAGE

discussed above. The test case analyses were applied to three air bases. Land areas within the resulting contours were then evaluated and compared.

The four test case combinations chosen for this study are shown below:

	Propagation Condition		
Case	G-G Propagation	G-G to A-G Transition	Shielding
1	BBN	BBN	None
2	SAE	SAE	None
3	SAE	SAE	SAE
4	A-G	None	None

Note that the Case 1 conditions conform to the existing data base and the unmodified version of NOISEMAP. Cases 2 and 3 differ from Case 1 in their application of the SAE algorithms. Case 4 eliminates altogether the concept of two propagation modes by substituting air-to-ground noise level curves in place of the ground-to-ground ones.

Each of these cases was applied to 3 representative air bases:

- Eglin AFB, Florida - primarily a mixed fighter base, consisting of F-4, C-9 and C-141 operations
- Grissom AFB, Indiana - a Strategic Air Command (SAC) base, dominated by KC-135 and B-52 operations.
- Vance AFB, Oklahoma - a training base with almost exclusively T-37 and T-38 activity.

Under previous studies the data base for each of these facilities had been assembled and a baseline set (Case 1) of Day-Night Average Level (DNL) contours prepared. Under the current study, NOISEMAP and/or the noise data base were modified to embody the above combinations of sound propagation algorithms. DNL contours (65, 70, 75, 80, 85 dB) were computed using each of the alternative algorithms. The air base operations portion of the data base, however, remained unchanged.

Figure IV-5 shows a typical contour set, in this case Eglin AFB. DNL 65 and 75 contours are shown for baseline conditions and two of the alternative sets of algorithms. A brief inspection of the figure quickly reveals that the geographic areas most affected are those along the runway sideline and those well to the side of major flight paths (locations where observers would view a passing aircraft at relatively low angles of elevation). In these areas, noise level predictions vary as much as 10 decibels between algorithms.

In contrast, the least affected areas are directly beneath the flight paths, and were it not for the small contribution of nearby paths the direct overflight areas would be totally unaffected by the algorithm changes. The nearby paths, of course, are likely to be viewed at low elevation angles and their contribution will, in fact vary with the particular propagation model employed. Thus, the total noise environment in these areas will also vary incrementally depending on the propagation algorithm uses.

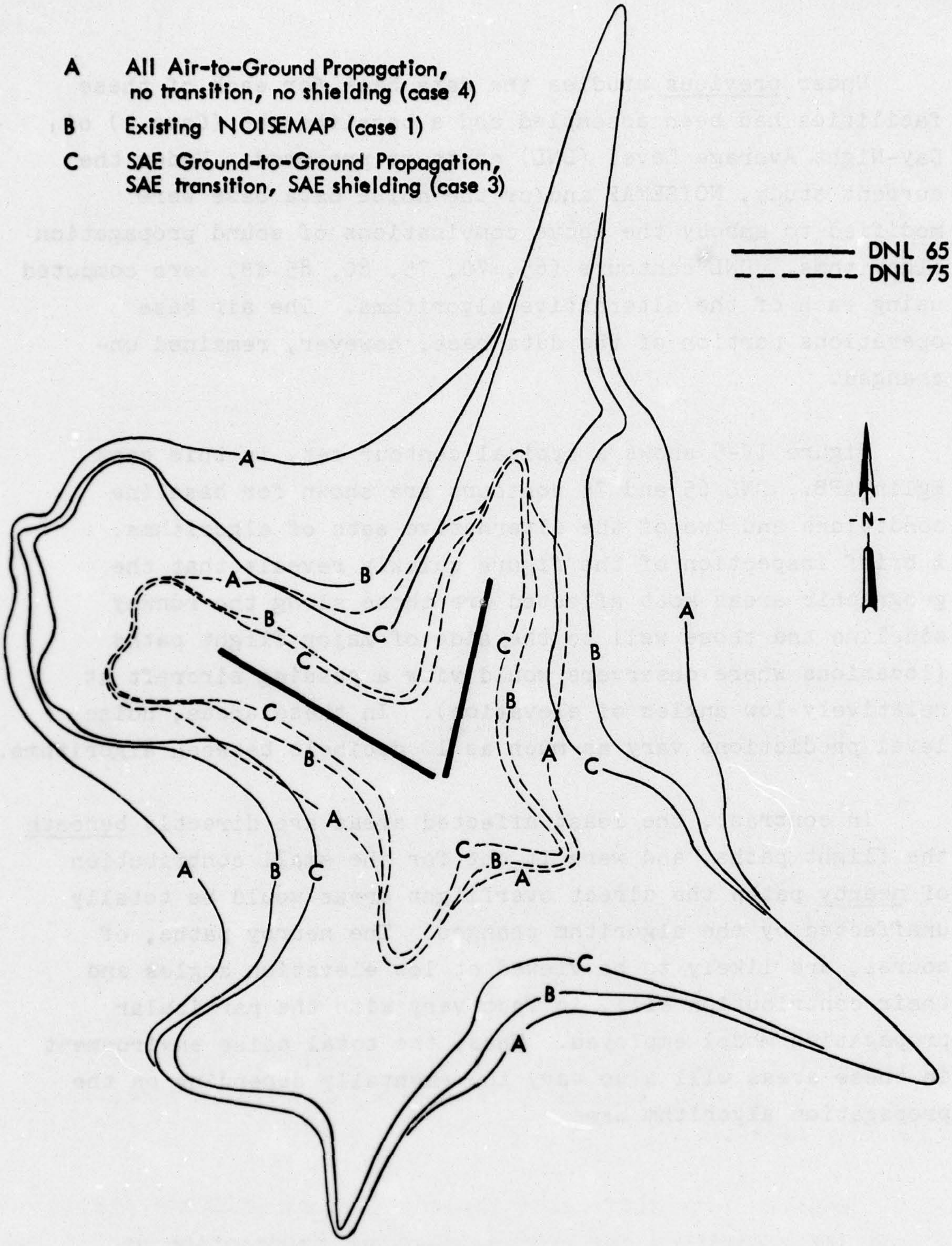

FIGURE IV-5. TYPICAL CONTOUR IMPACT OF MODIFIED PROPAGATION ALGORITHMS (EGLIN AFB)

As a means of quantifying the impact of the alternative algorithms,land areas within each contour were calculated. Tables, IV-1, IV-2, and IV-3 present the contour areas and the percentage deviation from the baseline case. In general, the introduction of the SAE algorithms resulted in contour size *reduction*, while the elimination of the ground-to-ground propagation mode was manifested in *increased* contour size.

A comparison of the DNL 65 decibel contour areas for the three bases reveals that the Case 2 conditions result in a 3 to 6 percent area reduction; but with the introduction of shielding, the Case 3 condition bring about a 13 to 18 percent decrease. An 11 to 30 percent increase occurs when air-to-ground is substituted for ground-to-ground propagation.

Somewhat larger percentage area changes are observed for the DNL 75 dB contours. Case 2 results in a 6 percent area reduction; Case 3, a 17 to 22 percent reduction. Case 4 a 14 to 42 percent increase.

Conclusions and Recommendations

The results of this investigation reaffirm general conclusions of the previous study of noise contours of individual aircraft - that "low angle" sound propagation algorithms result in sizable contour differences, especially along the runway sideline.

However, the difference between current NOISEMAP (BBN) and SAE algorithms for ground-to-ground propagation and

transition result in relatively moderate area changes (order of 3 to 11 percent for DNL 65 to 75 dB contours). The addition of SAE shielding algorithm to the other SAE algorithms results in sizable total area reductions (13 to 22 percent) compared to current NOISEMAP propagation algorithms. Compared to computations ignoring ground-to-ground propagation altogether (Case 4), the SAE algorithms (Case 3) result in area reductions of 25 to 45 percent of the DNL 65 to 75 dB contours.

Because there is so little technical evidence to show that one set of propagation and transition algorithms is more accurate than the other, we recommend that:

(a) Current NOISEMAP algorithms for ground-to-ground propagation and for transition between modes of propagation be retained until further technical analyses or data show a clear basis for alterations.

(b) Technical studies, utilizing field measurements be undertaken to develop basis for improved algorithms.

With regard to the shield algorithm we recommend that no shield correction be incorporated in NOISEMAP <u>at this time</u>, but that technical studies be continued as recommended in Reference 11.

TABLE IV-1
DAY NIGHT AVERAGE LEVEL (LDN) CONTOUR
AREAS FOR EGLIN AFB

	Propagation Condition				LDN CONTOUR				
Case	G-G Propagation	G-G to A-G Transition	Shielding	Statistic	65	70	75	80	85
1	BBN	BBN	None	Total Area(mi^2)	30.20	14.38	7.19	3.71	2.11
				Area Difference(mi^2)	--	--	--	--	--
				Area Difference(%)	--	--	--	--	--
2	SAE	SAE	None	Total Area(mi^2)	28.27	12.95	6.42	3.44	2.11
				Area Difference(mi^2)	-1.93	-1.43	-0.77	-0.27	0.00
				Area Difference(%)	(-6.4)	(-9.9)	(-10.7)	(-7.4)	(0)
3	SAE	SAE	SAE	Total Area(mi^2)	24.76	11.10	5.61	3.03	1.86
				Area Difference(mi^2)	-5.44	-3.28	-1.58	-0.68	-0.25
				Area Difference(%)	(-18.0)	(-22.8)	(-22.0)	(-18.3)	(-12.1)
4	A-G	None	None	Total Area(mi^2)	39.32	19.64	10.23	5.34	2.81
				Area Difference(mi^2)	9.12	5.26	3.04	1.63	0.70
				Area Difference(%)	(30.2)	(36.6)	(42.4)	(44.0)	(32.8)

TABLE IV-2
DAY NIGHT AVERAGE LEVEL (LDN) CONTOUR

AREAS FOR GRISSOM AFB

	Propagation Condition				LDN CONTOUR				
Case	G-G Propagation	G-G to A-G Transition	Shielding	Statistic	65	70	75	80	85
1	BBN	BBN	None	Total Area(mi^2)	159.06	54.35	24.70	10.11	4.13
				Area Difference(mi^2)	--	--	--	--	--
				Area Difference(%)	--	--	--	--	--
2	SAE	SAE	None	Total Area(mi^2)	150.84	49.05	22.48	9.27	3.87
				Area Difference(mi^2)	-8.22	-5.30	-2.22	-0.84	-0.26
				Area Difference(%)	(-5.2)	(-9.7)	(-9.1)	(-8.3)	(-6.2)
3	SAE	SAE	SAE	Total Area(mi^2)	132.80	41.91	19.95	8.35	3.48
				Area Difference(mi^2)	-26.26	-12.44	-4.75	-1.76	-0.65
				Area Difference(%)	(-16.5)	(-22.9)	(-19.4)	(-17.5)	(-15.9)
4	A-G	None	None	Total Area(mi^2)	177.31	62.66	28.12	11.57	4.78
				Area Difference(mi^2)	18.25	8.31	3.42	1.46	0.65
				Area Difference(%)	(11.5)	(15.3)	(13.7)	(14.5)	(15.6)

TABLE IV-3
DAY NIGHT AVERAGE LEVEL (LDN) CONTOUR
AREAS FOR VANCE AFB

Propagation Condition					LDN CONTOUR				
Case	G-G Propagation	G-G to A-G Transition	Shielding	Statistic	65	70	75	80	85
1	BBN	BBN	None	Total Area(mi^2)	28.15	14.77	8.00	4.34	2.51
				Area Difference(mi^2)	--	--	--	--	--
				Area Difference(%)	--	--	--	--	--
2	SAE	SAE	None	Total Area(mi^2)	27.10	14.28	7.48	4.10	2.41
				Area Difference(mi^2)	-1.05	-0.49	-0.52	-0.24	-0.10
				Area Difference(%)	(-3.7)	(-3.3)	(-6.5)	(-5.3)	(-3.7)
3	SAE	SAE	SAE	Total Area(mi^2)	24.60	12.83	6.66	3.82	1.79
				Area Difference(mi^2)	-3.55	-1.94	-1.34	-0.52	-0.72
				Area Difference(%)	(-12.6)	(-13.1)	(-16.8)	(-11.8)	(-28.7)
4	A-G	None	None	Total Area(mi^2)	33.68	17.79	9.72	5.04	2.88
				Area Difference(mi^2)	5.53	3.02	1.72	0.70	0.37
				Area Difference(%)	(19.6)	(20.4)	(21.4)	(16.2)	(14.9)

V. EFFECTS OF CLIMATIC VARIATIONS ON NOISE EXPOSURE

In previous studies,[7] the effects of annual climatic extremes on noise exposure were investigated for two airport situations. The current study extends the initial investigations to more complex airport conditions with a greater range of temperature and relative humidity. In addition to the study of changes in noise exposure, the climatic conditions at a number of bases were reviewed and subjected to a statistical analysis.

Base Climatological Data

The noise exposure due to aircraft operations depends on a number of parameters, one of which is the absorption of sound energy along the propagation path between the source and the observer. The air absorption is a function of the temperature and relative humidity of the atmosphere, and this section discusses some of the aspects of these variables for a number of bases.

A criterion for determining the necessity of using other than standard noise data was provided in Reference 2. This criterion is based on the dependence of air absorption on the absolute humidity of the atmosphere. This in turn can be approximated by the product of temperature and relative humidity, T x R.H. The "standard" atmospheric conditions for calculation of noise propagation are 59°F and 70% R.H. At a value of T x R.H. of 2000, the absorption is approximately 30% higher than for standard conditions, causing the noise levels to fall off more rapidly with distance. This value of 2000 was set as the criterion level, requiring additional computation if the T x R.H. is below this level for three months or more.

Data for 23 bases were assembled and analyzed with respect to temperature, relative humidity and their product. Climatic conditions were obtained from Air Weather Surface Climatic Briefs or from Local Climatological Data Summaries for weather stations at or close to each base. These documents provide average data over a period of time which includes daily maximum and minimum temperatures by month and similar averages for relative humidity at specified times of day. The relative humidity data does not necessarily coincide in time with the maximum and minimum temperatures. However, the rate of change of the parameters during the day is relatively slow, so for the purposes of this study, it was assumed that the maximum reported relative humidity corresponded to the minimum temperature, and that the minimum relative humidity corresponded to the maximum temperature.

The data were tabulated on a month-to-month basis for statistical analysis. The format consisted of lists of the average daily maximum and minimum temperatures and relative humidities for each month at each base. The values and their product were then analyzed to give values of mean and standard deviation of average maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity and the products for the following combinations:

(1) By base, average for all months
(2) By month, average for all bases
(3) By base, average for all months, average daily values
(4) By month, average for all bases, average daily values
(5) All data, month and base
(6) All data, month and base, average daily values.

Tables V-1 and V-2 summarize this information. Also included in Table V-1 is a listing of the number of months during which the average value of T x R.H. is less than 2000. Of the 23 bases studied, 8 have one or more months below the 2000 criterion, and five have three or more months. It is interesting to note that the low values of T x R.H. occur *only* during the cold part of the year, and *none* as a result of low humidity in the summer months.

In reviewing the tabulated values with respect to the criterion, it should be remembered that the values listed are derived from the average over a one-month period, and do not reflect the daily variation. Very low values of T x R.H. (sometimes negative) can occur in the early morning hours due to low temperature. Thus the recommended procedures for computing noise exposure do not take into account variations throughout the day, but consider only average conditions. This is consistent with normal practice and with the procedures used in defining noise exposure, thus separate consideration of variations throughout the day are not necessary.

The selected sample of 23 bases represents only part of the entire population of airports throughout the country, and may not yield true averages for the various parameters. However, the bases sampled are distributed across the contiguous 48 states, and the values may be considered typical.

Noise Contours for Three Bases

Using the climatic conditions presented above as a guide, three bases were selected for detailed study. The considerations in selecting these bases included:

(1) T x R.H. less than 2000 for at least 3 months
(2) Different types of aircraft and/or missions at the bases
(3) Availability of complete operational information
(4) Availability of contours for standard conditions.

Three bases meeting these requirements were Minot AFB, North Dakota; Malmstrom AFB, Montana; and Buckley ANGB, Colorado. Two additional sets of contours were computed for each base, representing the months having the maximum and minimum product of T x R.H. Noise versus distance relationships for the aircraft were calculated using the Aerospace Medical Research Laboratory OMEGA 6.6 and 8.2 programs. Typical examples of the various conditions are show in Figures V-1 through V-10.

The changes in takeoff and climb performance were also computed for all aircraft at each base. Typical examples of these are shown in Figures V-11 through V-15.

The operational data for the three bases are summarized in Table V-3.

The information listed above was processed using NOISEMAP 3.2 to generate DNL values over a grid. From this, the areas enclosed by the various noise contours were computed. Table V-4 summarizes the the area changes, and the comparative contours for Minot AFB are shown in Figure V-16.

With one exception, the contours for non-standard conditions are smaller by up to 60 percent. The exception is the DNL 60 contour for Buckley ANGB at the higher temperature, resulting in a 0.5 percent increase. The largest change is for the cold day condition at Minot, where the DNL 65 contour is 60.7 percent smaller, compared with about 35 percent for the other contours

at the base. This large difference can be attributed to the extended traffic pattern, which creates a fairly large area exposed to slightly over DNL 65. This area shrinks considerably at the low temperature as a result of a moderate reduction in noise level. Changes at the other two bases are more uniform among the contours, approximately 28 percent at Malmstrom, 21°F and 64% RH, and about 23 percent at Buckley, 30°F and 54% RH.

The data presented in Table V-4 also allows one to develop an approximate relationship for estimating changes of area with changes in air absorption. A plot of the air absorption at 1000 Hz* vs area ratios for the 3 bases on a log-log paper show an approximate linear relationship and leads to the following expression for relating changes in area to air absorption for DNL 65 to 75 contour areas:

$$A_i = 1.235 \cdot C_i^{-0.521} \approx \frac{1.23}{\sqrt{C_i}} \qquad \text{(V-1)}$$

where A_i is the ratio of the DNL contour area for temperature and relative humidity conditions i to the contour area for standard day conditions, and C_i is the air absorption coefficient (in dB per 1000 ft.) at 1000 Hz for temperature and relative humidity conditions i.

The above approximate relationship is useful in estimating the change in contour size for other than standard day conditions. For example, the expression indicates a change of about 0.3 dB per 1000 ft in the absorption coefficient results in a 10

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* See the following subsection for discussion of the basis for using the air absorption at 1000 Hz.

percent change in contour area. For an air absorption coefficient of 2 dB per 1000 ft. at 1000 Hz (which corresponds roughly to the product of T x R.H. = 2000), Equation V-1 indicates a reduction in area of approximately 17% compared to standard day conditions.

Comparison of Equation V-1 with the relationship between area and DNL given by Equation V-1 (of Appendix A) shows that a 10 percent change in absorption (in dB per 1000 feet at 1000 Hz) translates into an approximate 0.8 dB change in DNL.

Review of Criteria

The recommendation from Reference 2 requires calculation of noise exposure using other than the "standard" noise curves when the product T x R.H. is less than 2000 for three months or more. It would clearly be desirable for most planning purposes to develop only one set of contours rather than contours for seasonal or monthly conditions. It is then necessary to determine the weather conditions to be used for this single contour set.

A review of Table V-1 indicates that taking the annual average T x R.H. is not satisfactory. As an example, the annual average T x R.H. at Edwards AFB is 2568 with no months below 2000, whereas Grand Forks AFB has an annual average T x R.H. which is essentially the same, 2580, with 5 months below 2000 and a much greater range of T x R.H. throughout the year.

A possible procedure which may be considered is the use of an average set of absorption data. To analyze this rigourously, it would be necessary to take the entire year's data

and list the absorption coefficient by band for each month, and then to determine the average for each band. The application of these values is not compatible with the OMEGA 6.6 or 8.2 programs used to generate noise versus distance relationships. Using the tabulation of absorption values in SAE ARP 866, values of R and R.H. could be selected which approximate the absorption spectrum obtained by averaging. This would then be used as input to OMEGA 6.5 and 8.2. Thus an approximate but tedious method exists for defining the noise relationships to be used to produce an "annual average" noise contour set.

A less complex procedure can be used based on the absorption coefficient in only one band. The approach used is to determine a set of meteorological conditions which is representative of the entire year. First, it is necessary to determine which frequency band has the most effect on the rolloff of noise level versus distance. Table V-5 lists the A-weighted noise level as a function of distance for four types of aircraft, selected because of their frequent occurrence at a number of bases. The values were derived from the OMEGA 6.5 output for these aircraft at the standard conditions of 59°F and 70% RH. Allowing for inverse square propagation, the effective rate of air absorption can be calculated, as tabulated in Table V-6. The effective absorption varies with distance as the spectrum changes. Between 1000 feet and 2000 feet, the value is 2.4 dB/ 1000 feet; between 2000 feet and 4000 feet, the value is 1.6 dB/ 1000 feet, etc. These values can be related to the absorption values tabulated in SAE ARP 866 to determine which frequency band controls the rolloff. The area between 2000 feet and 4000 feet from the aircraft is frequently significant in terms of noise exposure, and in this region, the excess absorption corresponds to the absorption at 1000 Hz for the standard day

conditions. Thus the 1000 Hz band is the most significant in this area. It is therefore convenient to work with the 1000 Hz band to determine the "typical" climatic conditions for a base. The choice of this band is probably not critical, and similar results could e obtained using another frequency.

Figure V-17 shows the variation of the absorption coefficient in the 1000 Hz band as a function of temperature and relative humidity. A noteable feature of this graph is the relatively slow change of absorption coefficient up to a value of approximately 2.0; at lower temperatures and/or humidities, the value increases rather more sharply. The line tracing out a value of 2.0 follows very closely with the criterion of T x R.H. = 2000, as shown on the graph.

This graph (as well as the tables provided in Reference 9) can be applied to calculation of temperature and relative humidity for annual average conditions. As noted above, a simple T x R.H. average is not sufficient. One procedure is to calculate the absorption coefficient for each month, and calculate the average coefficient for the year. A combination of temperature and relative humidity is then selected which has this value. There will be a range of values meeting this requirement, and the value selected should be close to one of the monthly values for the base. Typical examples of this are shown for three bases in Figures V-18 through V-20.

The simple averaging of absorption coefficients has the disadvantage that in some cases(where one or two months have exceptionally high or low air absorption values) the average may not represent a time-weighted average. A somewhat more

sophisticated approach would be to determine the *logarithmic* average of the monthly absorption coefficients. For a given set of monthly values, the logarithmic average yields a number equal to or slightly smaller in magnitude than the arithmetic average. However, for most sets of data, the differences between the two averages are likely to be quite small.

An alternate simple procedure that will generally provide a better time weighting of the absorption coefficients is to list the absorption coefficients for each month, then simply select the absorption coefficient (and corresponding temperature and humidity) for the sixth lowest value. This assures that there are five months with contours equal or larger in size, and six months with contours equal or smaller in size than those for the values selected.

Application of the three averaging procedures discussed above to the monthly data for the three bases studied yields the results given in Table V-7. Absorption coefficients, and corresponding months having suitable average temperature and relative humidity values, are listed for the arithmetic average, logarithmic average and the sixth lowest monthly value. Note the small differences between arithmetic and logarithmic averages, and that the sixth lowest value (58th percentile) is smaller than the average values for two of the three bases studied.

Conclusions and Recommendations

The data developed in this report demonstrate the appreciable variation in noise exposure as a function of climate. The study shows that during periods of cold weather, even at

moderately high relative humidities, the reduction in noise exposure can be 4 to 5 dB. Under these conditions, the use of standard noise and performance data can indicate an unrealistically high noise exposure for some months of the year. In some cases, this may not be considered important, because these effects *always* occur as a result of low temperatures. This implies two other effects, first that the emphasis on outdoor activities would be less, and secondly that building construction designed for the cold climate would generally be more substantial, and that windows would be closed, providing greater outside-to-inside noise reductions.

The analysis also shows that contours based on standard day conditions are usually quite representative for other than some low temperature conditions. Except for those few cases where T x R.H. is less than 2000 or monthly temperatures exceed about 90°F, use of standard day conditions will yield contours that are approximately within $\pm$ 10 to $\pm$ 15 percent of the areas of contours developed using monthly data.

However, since the new noise file programs make the calculation of noise curves for any temperature or humidity a trivial computational task, there is a decided advantage from the standpoint of achieving local community acceptance of developing contours that are based upon actual "typical" base conditions. We recommend that selection of representative base temperature and relative humidity be based upon the sixth lowest monthly average absorption coefficient. Specifically, we recommend that selection follow these steps:

(1) Determine the average monthly temperature and relative humidity for each month from either the Air Weather Surface Climatic Briefs or Local Climatological Data Summaries for weather stations at each base.*

(2) Determine the air absorption coefficient for the 1000 Hz 1/3 octave band from the tables of Reference 9 or from Figure V-17, and rank the absorption coefficients in ascending order from smallest to largest absolute values.

(3) Select the *sixth* smallest value of absorption coefficient and use the temperature and relative humidity corresponding to this value for specification of noise and performance data for that Air Force base.

Two variables not reviewed in this report are the effects of diurnal variations and non-homogeneous atmospheres. During the early morning hours, the temperature is below the average. However, in any given day, the total amount of moisture (absolute humidity) would not be expected to change appreciably, ie, as the temperature falls, the relative humidity rises. Thus, the change throughout the day should not be significant. The variability of atmospheric conditions with altitude can be more significant as shown in a study by FAA.[10] The use of surface weather conditions to determine absorption

* Where not given directly, monthly average values should be the arithmetic average of the "mean daily maximum" and "mean daily minimum" temperatures, and the arithmetic average of the highest and lowest relative humidity values listed for the month.

values could result in overestimating the noise exposure when there are temperature inversions and/or very dry air aloft. These conditions occur typically in desert regions. The existing procedures overestimate the noise exposure in these circumstances, and the current state-of-the-art does not icnlude consideration of these conditions.

TABLE V-1 SUMMARY OF CLIMATOLOGICAL DATA BY BASE

BASE	Avg.Max Temp.	Avg.Min. Temp.	Avg. Temp.	Avg.Max. RH	Avg.Min. RH	Avg. RH	Avg.Day TXRH	Avg.Night TXRH	Avg. TXRH	Max. TXRH	Min. TXRH	Months Below 2000
Bergstrom	78.8	57.4	68.1	83.6	53.3	68.5	4178	4843	4672	5749	3401	0
Blytheville	69.1	50.0	59.5	81.8	55.9	68.9	3815	4138	4163	5640	2573	0
Buckley	64.0	36.2	50.1	68.3	40.3	54.3	2507	2501	2699	3906	1642	3
Carswell	76.5	54.4	65.4	83.4	54.4	68.9	4126	4560	4503	5668	3158	0
Charleston	75.4	54.0	64.7	85.9	56.1	71.0	4266	4666	4627	6091	3380	0
Columbus	73.7	52.3	63.0	85.5	53.7	69.6	3930	4521	4397	5873	3010	0
Dobbins	70.3	51.3	60.8	83.3	57.3	70.3	4046	4327	4311	6002	2948	0
Edwards	76.7	46.5	61.6	59.3	28.0	43.7	2023	2642	2568	2805	2434	0
Grand Forks	48.7	28.0	38.3	77.8	59.1	68.5	2708	2265	2590	4761	132	5
Griffis	57.4	38.8	48.1	79.8	61.4	70.6	3438	3119	3368	4984	1699	2
Grissom	62.1	42.4	52.3	83.4	62.1	72.8	3784	3575	3789	5527	2075	0
Hurlburt	76.9	59.0	68.0	84.2	60.8	72.5	4671	4989	4935	6299	3781	0
Little Rock	72.6	49.3	61.0	84.3	57.5	70.9	4155	4198	4334	5939	2844	0
Malmstrom	55.9	33.9	44.9	65.8	44.7	55.2	2308	2220	2390	3344	1299	4
Maxwell	75.7	53.9	64.8	86.8	57.7	72.3	4371	4725	4708	6254	3412	0
McConnel	67.6	45.6	56.6	79.8	55.4	67.6	3675	3653	3799	5162	2254	0
Minot	50.3	28.8	39.5	77.5	56.9	67.2	2663	2259	2580	4487	423	5
Offutt	62.8	40.2	51.5	80.3	58.5	69.4	3585	3277	3556	5405	1624	2
Plattsburg	54.2	34.5	44.3	77.9	60.5	69.2	3218	2753	3076	4782	1106	4
Reese	73.6	45.8	59.7	74.3	44.0	59.1	3203	3443	3531	4704	2366	0
Seymour-Johnson	70.4	47.8	59.1	84.6	54.3	69.5	3865	4114	4162	5929	2592	0
Travis	73.2	47.4	60.3	81.9	46.4	64.2	3182	3850	3763	3913	3578	0
Whiteman	63.8	45.4	54.6	79.5	60.1	69.8	3753	3648	3791	5534	1943	1
Average	67.4	45.3	56.4	79.5	53.8	66.7	3542	3665	3603	5163	2334	-

NOTE: The values listed represent annual averages.

TABLE V-2 SUMMARY OF CLIMATOLOGICAL DATA BY MONTH

Month	Avg.Max Temp.	Avg.Min. Temp.	Avg. Temp.	Avg.Max. RH	Avg.Min. RH	Avg. RH	Avg.Day TXRH	Avg.Night TXRH	Avg. TXRH
January	44.0	23.9	33.9	76.9	61.0	68.9	2636	1898	2350
February	48.1	27.3	37.7	76.5	57.0	66.8	2674	2120	2502
March	55.4	34.0	44.7	76.8	53.6	65.2	2912	2633	2901
April	67.5	44.9	56.2	77.7	49.3	63.5	3326	3517	3585
May	76.6	53.6	65.1	80.1	50.4	65.3	3872	4339	4278
June	84.3	62.1	73.2	81.0	50.8	65.9	4279	5060	4841
July	88.8	66.0	77.4	80.7	49.7	65.2	4395	5354	5055
August	87.9	64.7	76.3	82.2	50.5	66.4	4424	5354	5076
September	80.7	57.6	69.1	83.4	53.4	68.4	4297	4834	4742
October	71.1	47.1	59.1	80.5	50.9	65.7	3603	3823	3893
November	57.3	35.7	46.5	79.7	57.0	68.3	3217	2866	3170
December	46.9	27.3	37.1	78.7	62.6	70.7	2871	2178	2609
Average	67.4	45.3	56.4	79.5	53.8	66.7	3542	3665	3603

TABLE V-3

AIR BASE OPERATIONAL SUMMARIES

Minot AFB		Malmstrom AFB		Buckley ANGB	
Aircraft Type	Daily Operations	Aircraft Type	Daily Operations	Aircraft Type	Daily Operations
A-4	0.300	A-4	1.240	A-4	15.280
B-52H	25.470	B-57	40.276	A-7	95.260
B-57	0.600	CT-114	2.570	C-9	10.452
C-141	0.600	C-9	1.470	F-100	8.540
C-9	0.400	F-106	12.855	F-101	9.060
F-101	0.500	F-111	5.000	F-4	6.820
F-106	27.450	KC-135A	4.900	T-37	4.780
F-5	0.200	T-33	13.800	T-38	9.670
KC-135A	36.460	T-38	0.560	T-39	6.940
T-33	12.850	T-39	3.080		
T-39	1.850	B-52	0.746		

TABLE V-4

DNL CONTOUR AREA CHANGES

Minot AFB

LDN CONTOUR	59° 70% AREA SQ. MI.	69° 66% AREA SQ. MI.	% CHANGE	6° 71% AREA SQ. MI.	% CHANGE
65	58.636	52.992	-9.6	23.024	-60.7
70	21.503	20.422	-5.0	13.564	-36.9
75	11.679	11.067	-5.2	7.595	-35.0
80	5.280	5.089	-3.6	3.491	-33.9
85	1.770	1.703	-3.8	1.129	-36.2

Malmstrom AFB

LDN CONTOUR	59° 70% AREA SQ. MI.	69° 45% AREA SQ. MI.	% CHANGE	21° 64% AREA SQ. MI.	% CHANGE
65	21.718	19.829	-8.7	14.575	-32.9
70	10.161	9.338	-8.1	6.870	-32.4
75	4.740	4.326	-8.7	3.310	-30.2
80	2.210	2.054	-7.1	1.710	-22.6
85	1.138	1.052	-7.6	0.897	-21.2

Buckley ANGB

LDN CONTOUR	59° 70% AREA SQ. MI.	73° 51% AREA SQ. MI.	% CHANGE	30° 54% AREA SQ. MI.	% CHANGE
60	24.432	24.554	0.5	19.960	-18.3
65	14.071	13.492	-4.1	10.386	-26.2
70	6.968	6.667	-4.3	5.122	-26.5
75	3.558	3.403	-4.4	2.659	-25.3
80	1.672	1.664	-0.5	1.310	-21.7
85	0.858	0.837	-2.4	0.670	-21.9

TABLE V-5 A-WEIGHTED LEVEL AS A FUNCTION OF DISTANCE

Aircraft Type	A-Weighted Sound Level				
	1000	2000	4000	8000	16000
B-52H	105.3	96.1	86.4	76.8	66.2
B-52G	114.2	106.2	97.2	86.8	74.6
F-4(Mil)	109.7	101.2	91.9	81.1	67.6
T-33	89.6	81.7	72.8	62.6	50.8

TABLE V-6 EFFECTIVE ABSORPTION VALUES

Aircraft Type	Effective Absorption, dB/1000 ft.			
	1000-2000	2000-4000	4000-8000	8000-16000
B-52H	3.2	1.8	0.9	0.6
B-52G	2.0	1.5	1.1	0.8
F-4(Mil)	2.5	1.7	1.2	0.9
T-33	1.9	1.5	1.1	0.7
Average	2.4	1.6	1.1	0.8

TABLE V-7

COMPARISON OF DIFFERENT METHODS FOR SELECTING THE AVERAGE ABSORPTION COEFFICIENT FOR THE YEAR

MINOT ANGB

Method	Absorp.Coeff.*	Typical Month
Arith. Avg.	2.12	November
Log. Avg.	2.04	October/November
Sixth Lowest	1.6	July or August

BUCKLEY ANGB

Method	Absorp.Coeff.*	Typical Month
Arith. Avg.	1.83	November
Log. Avg.	1.82	November
Sixth Lowest	1.7	July or August

TRAVIS ANGB

Method	Absorp.Coeff.*	Typical Month
Arith. Avg.	1.51	April or October
Log. Avg.	1.51	" "
Sixth Lowest	1.5	" "

* dB per 1000 feet

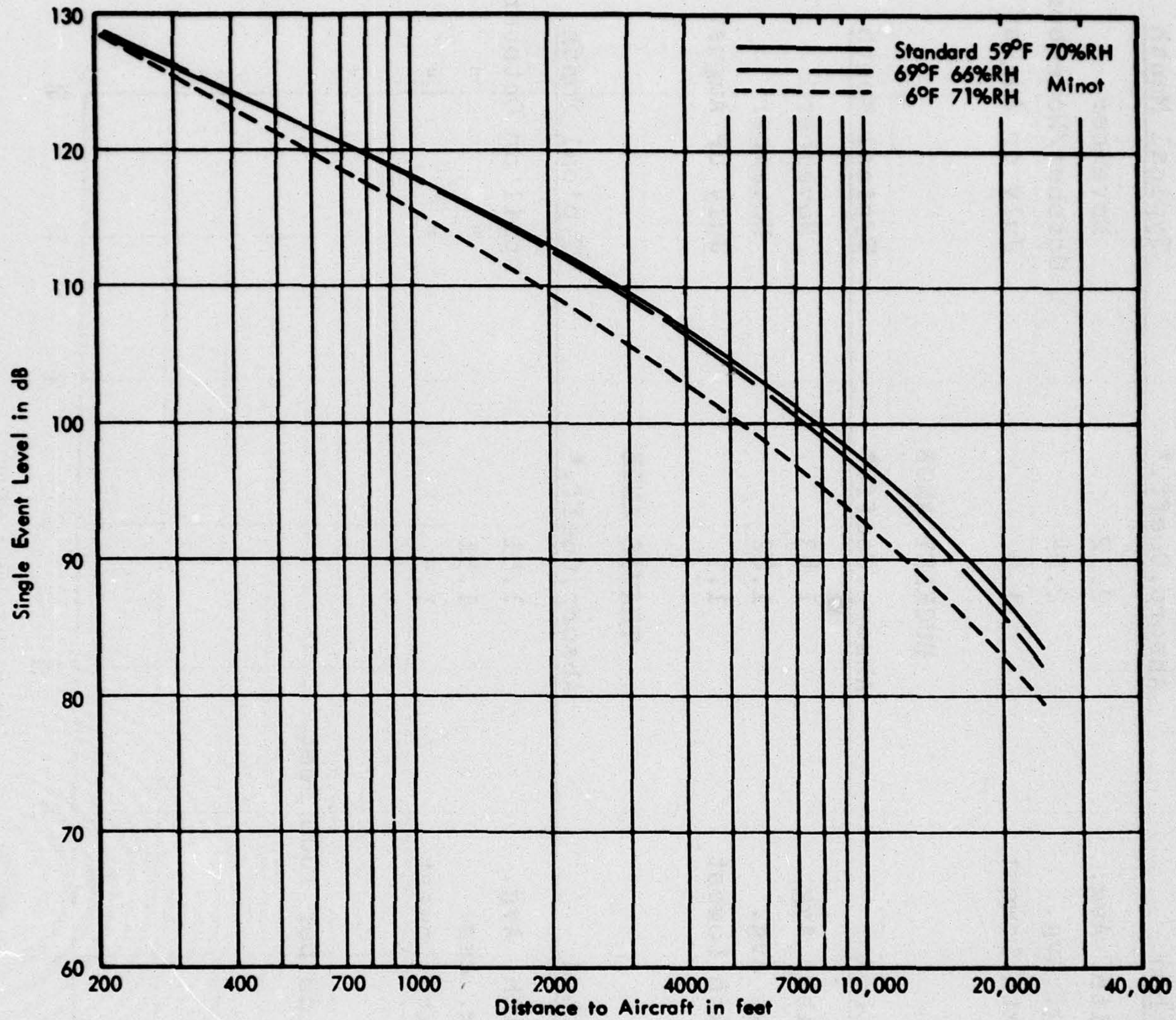

FIGURE V-1 KC-135A TAKEOFF POWER WET

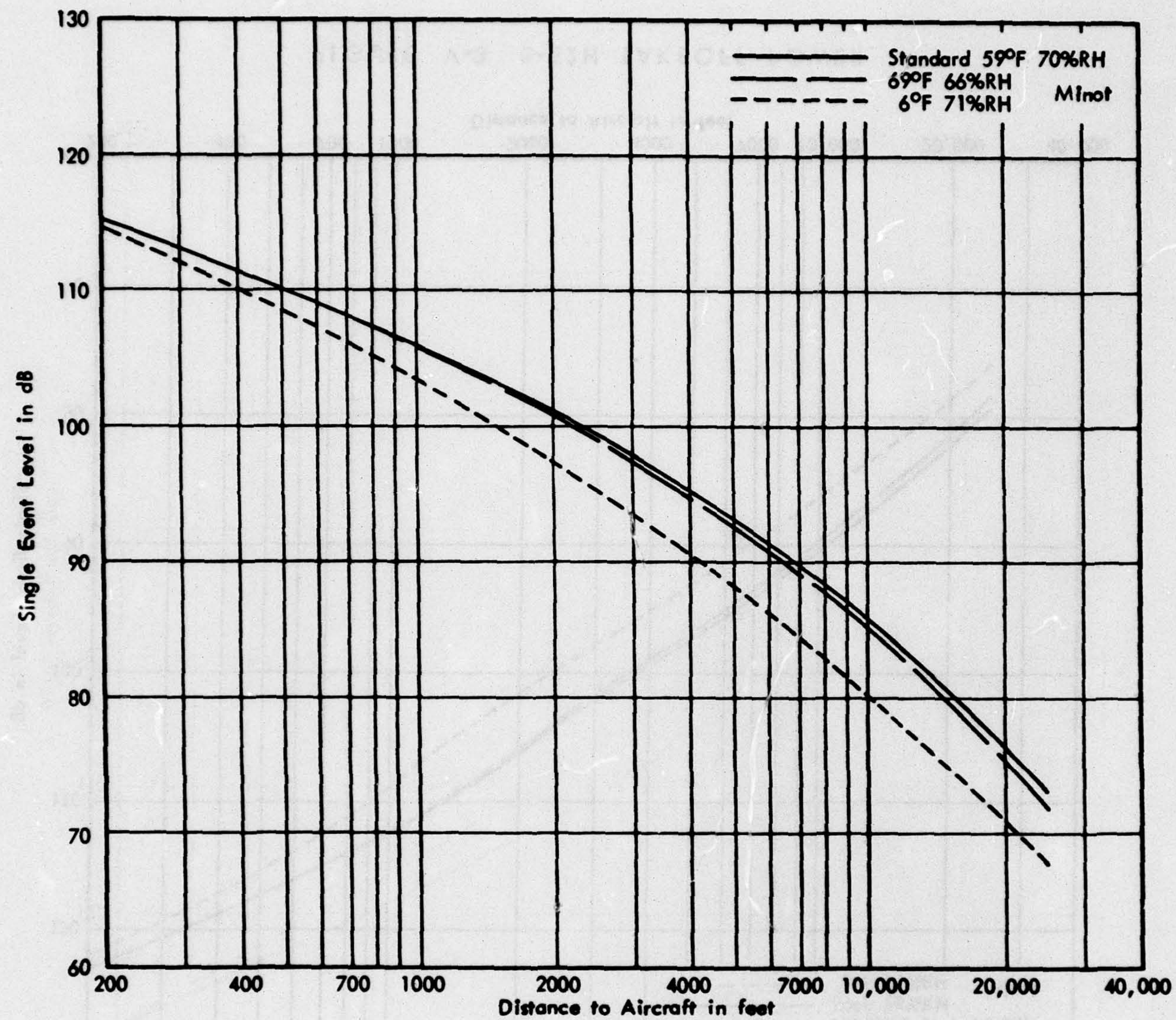

FIGURE V-2 KC-135A APPROACH

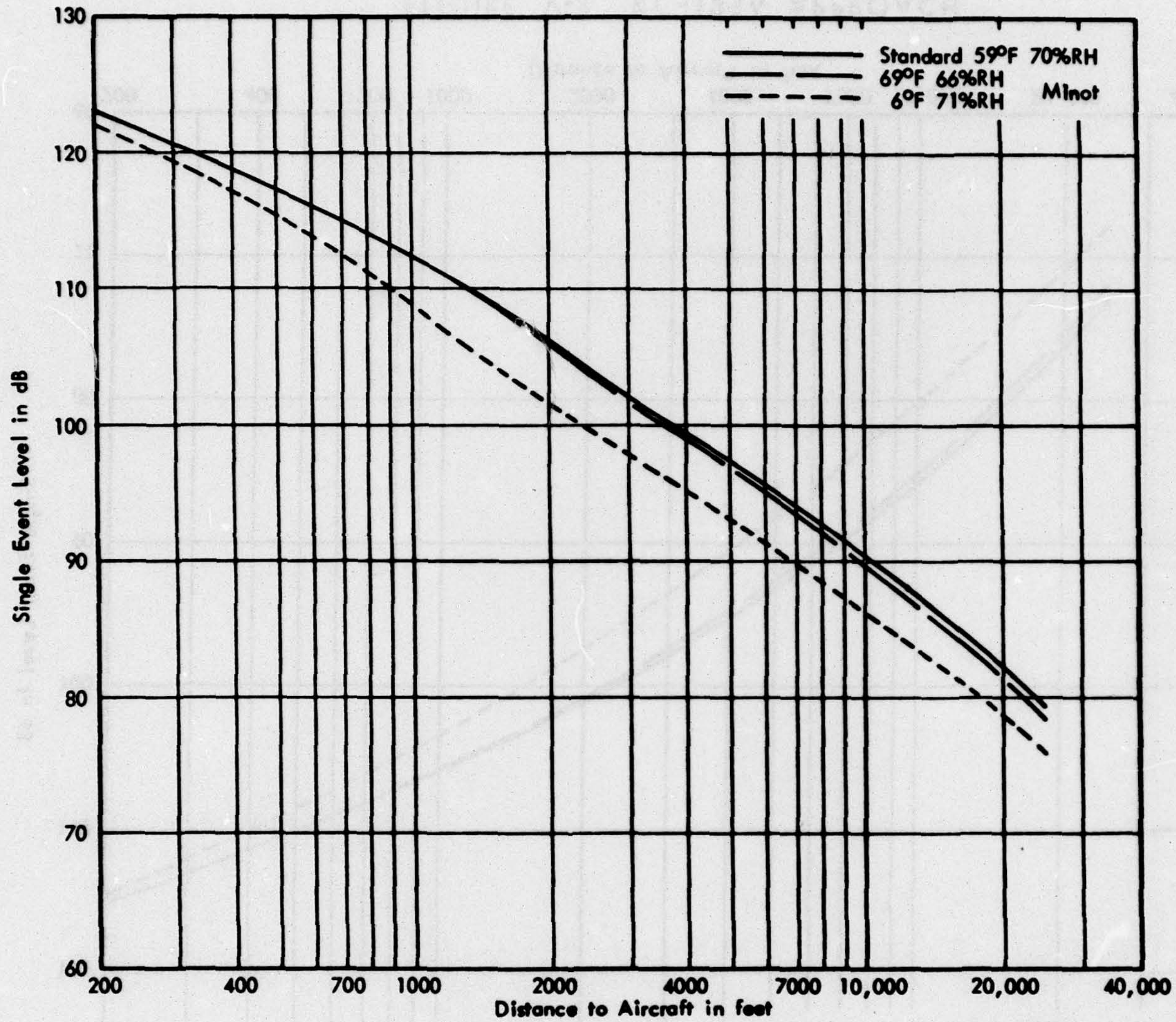

FIGURE V-3 B-52H TAKEOFF POWER

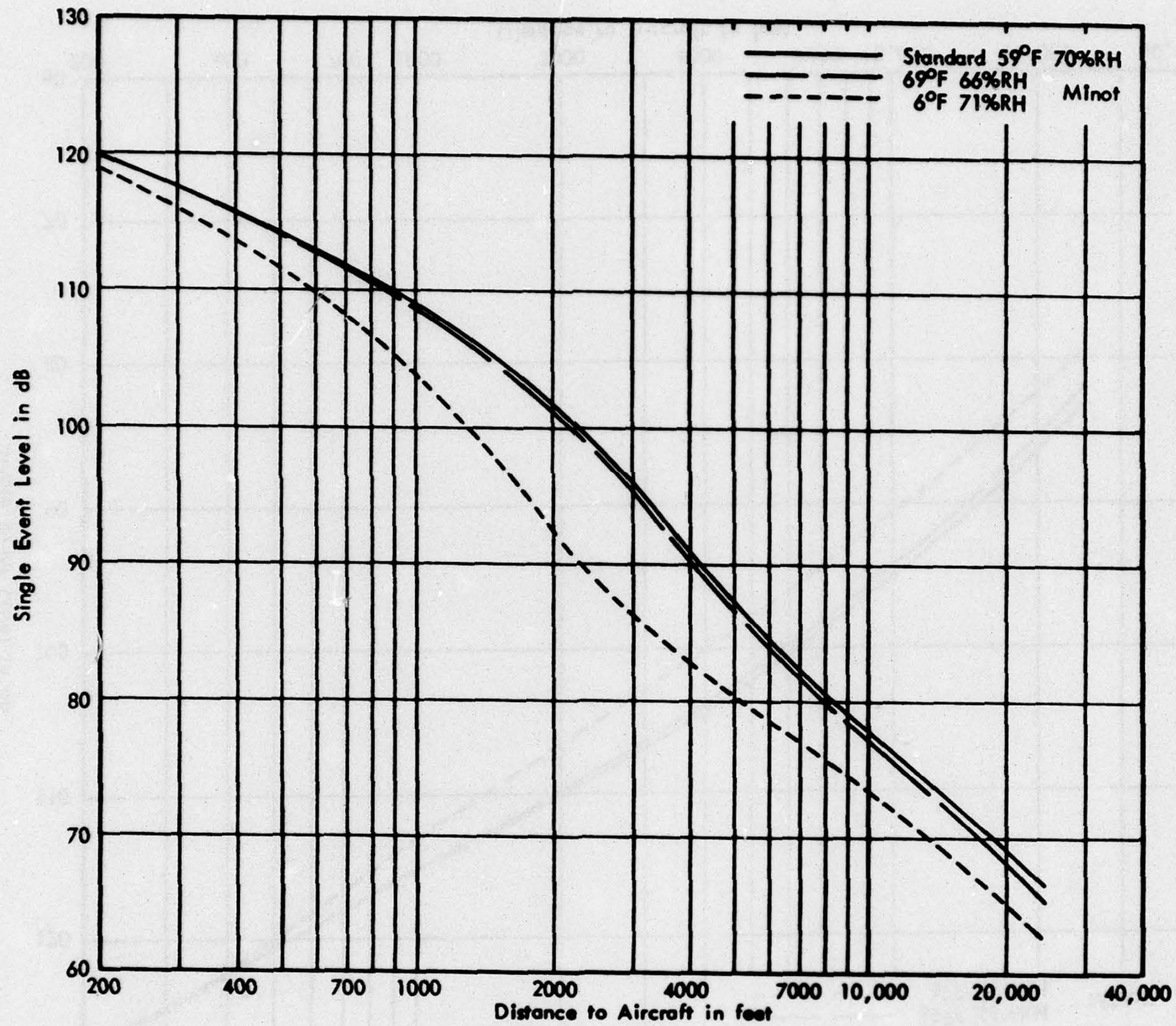

FIGURE V-4 B-52H APPROACH

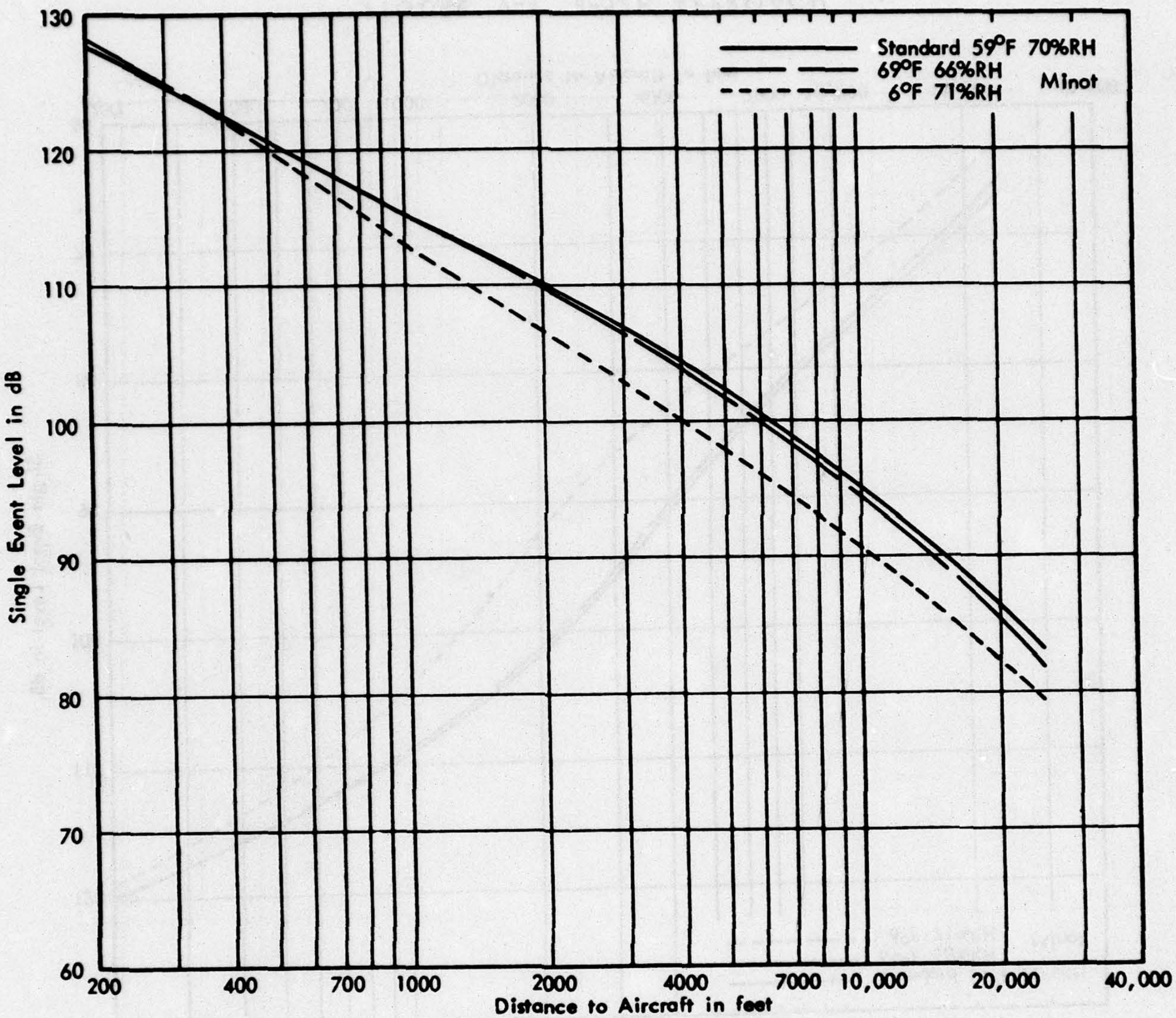

FIGURE V-5 F-106 AFTERBURNER

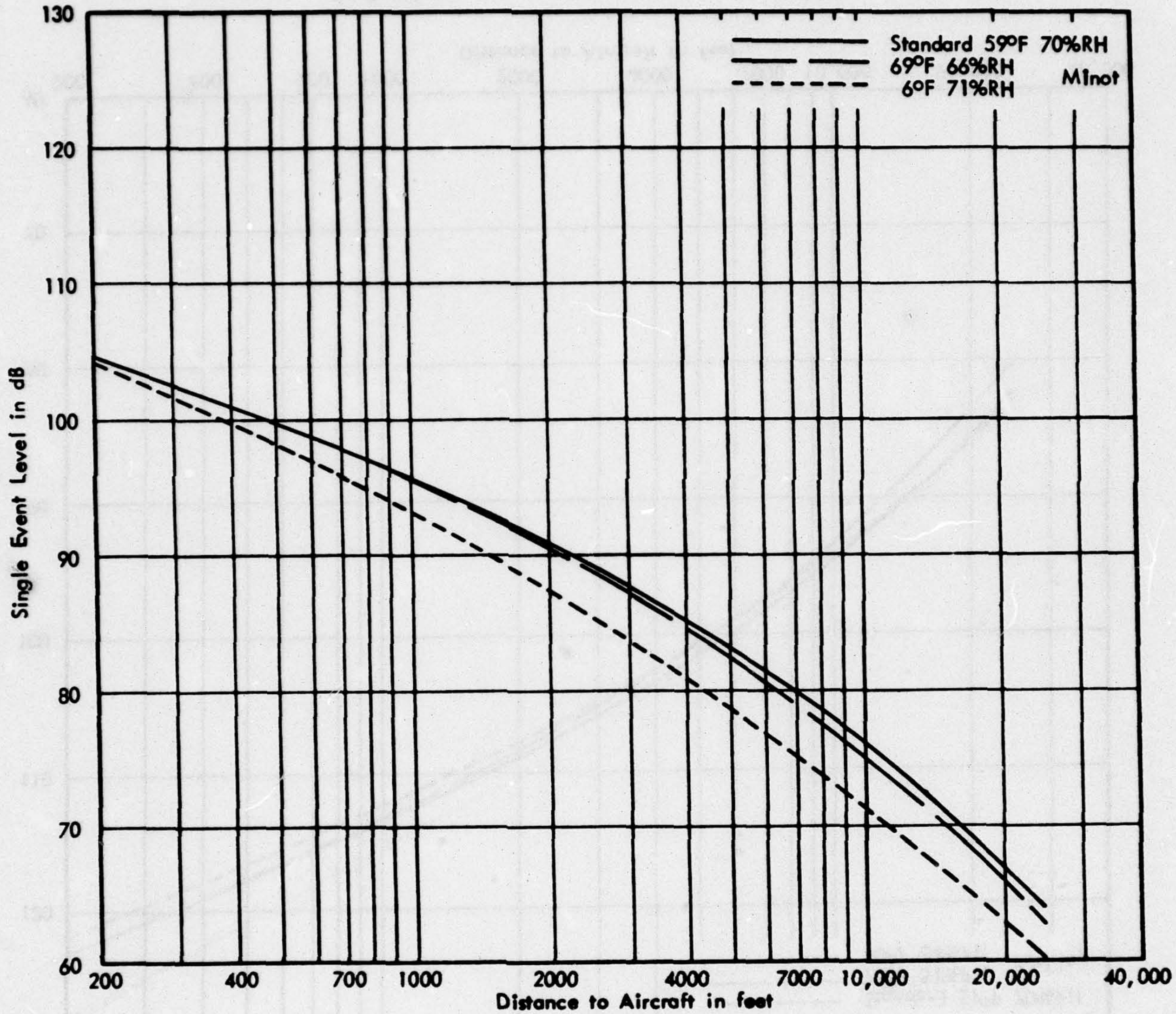

FIGURE V-6 F-106 APPROACH

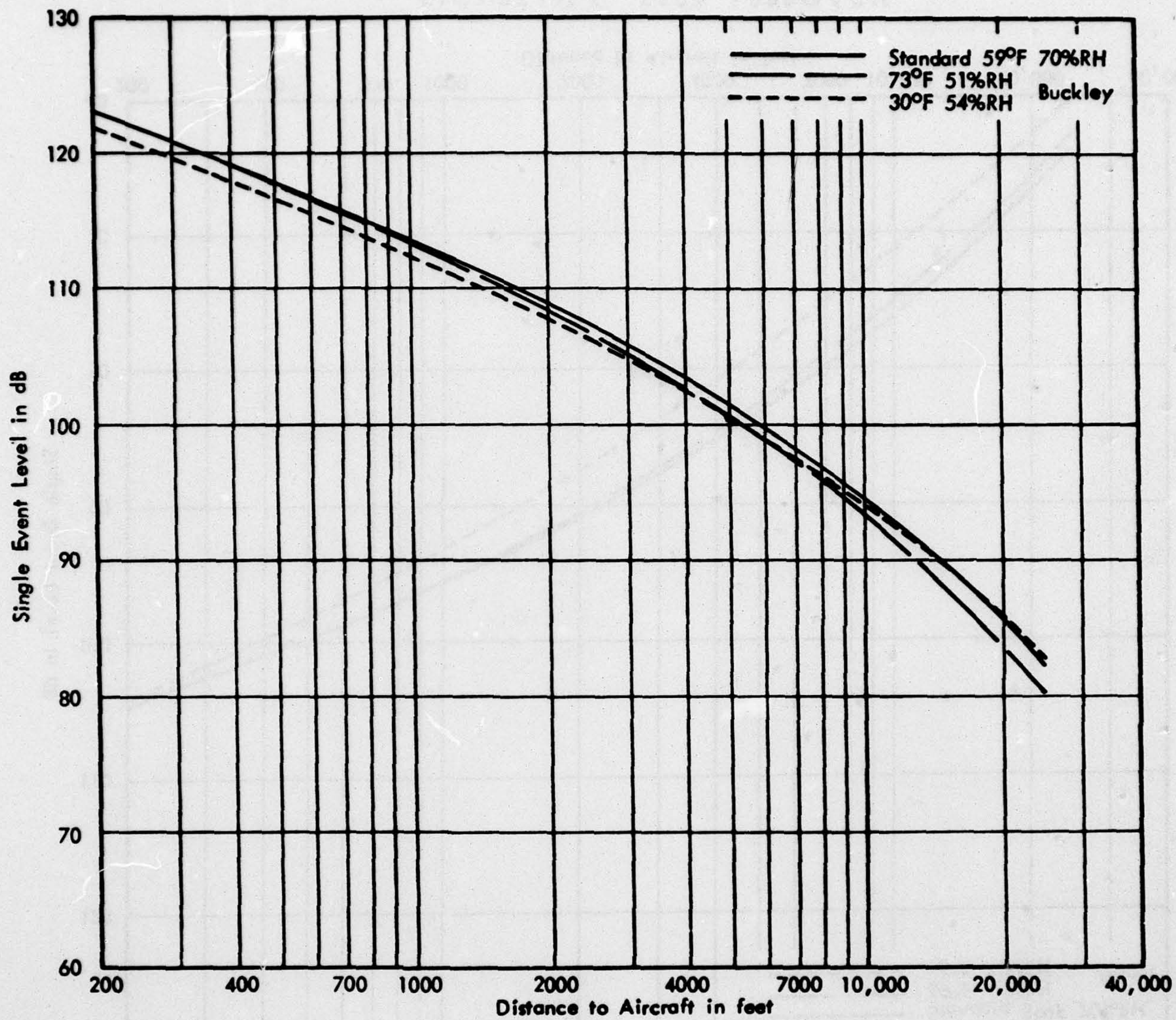

FIGURE V-7 F-100 AFTERBURNER

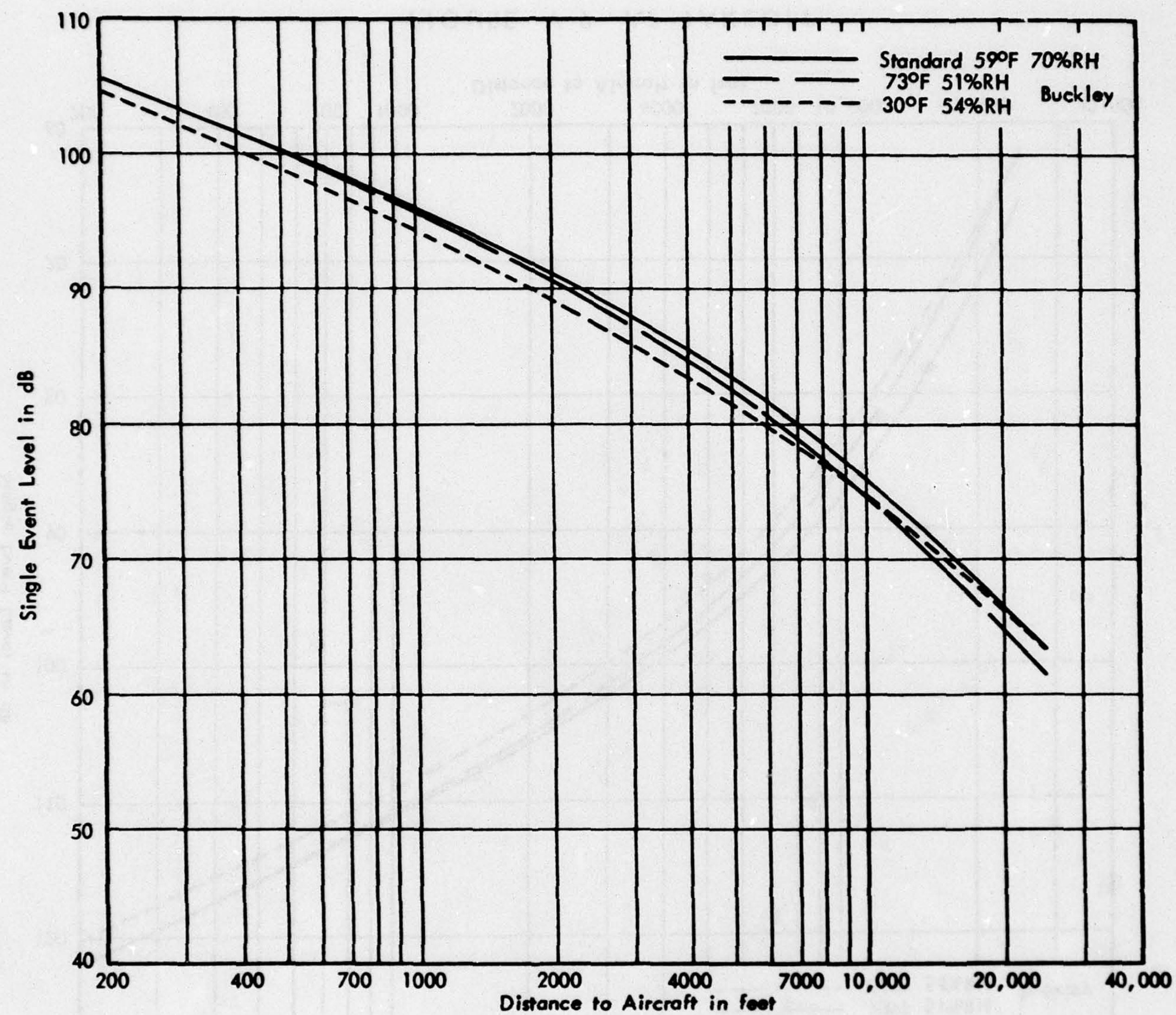

FIGURE V-8 F-100 APPROACH

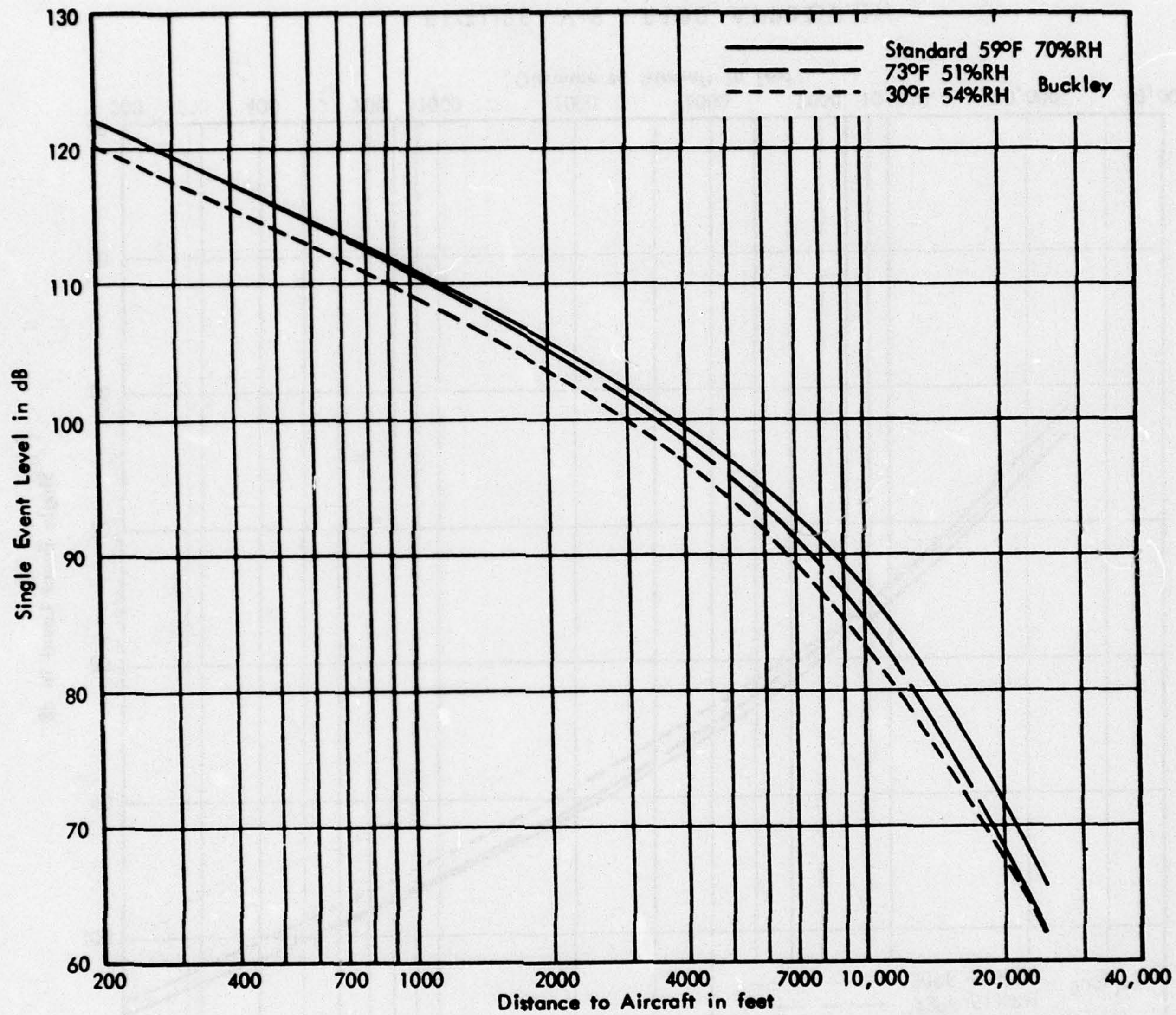

FIGURE V-9 A-7 TAKEOFF

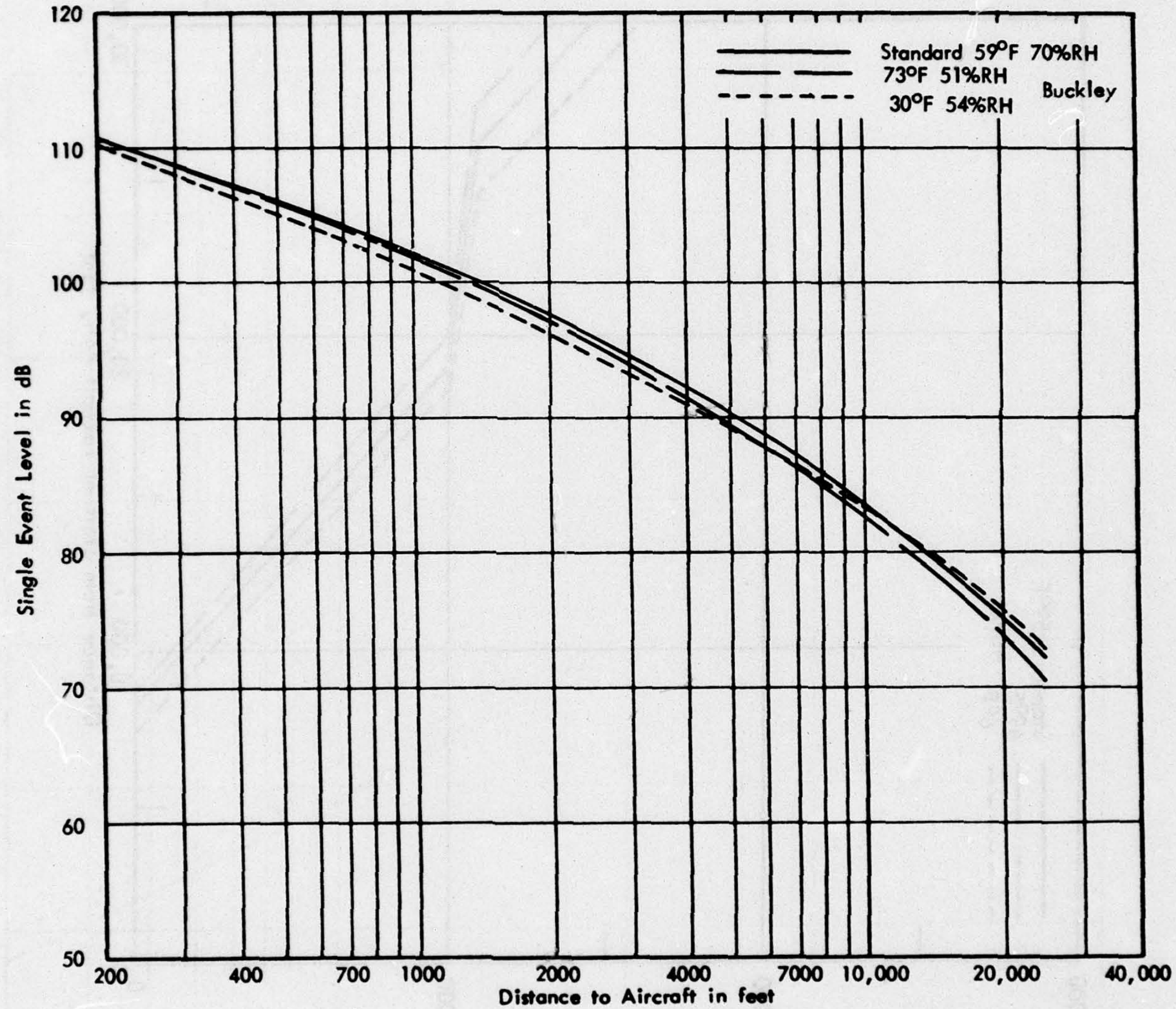

FIGURE V-10 A-7 APPROACH

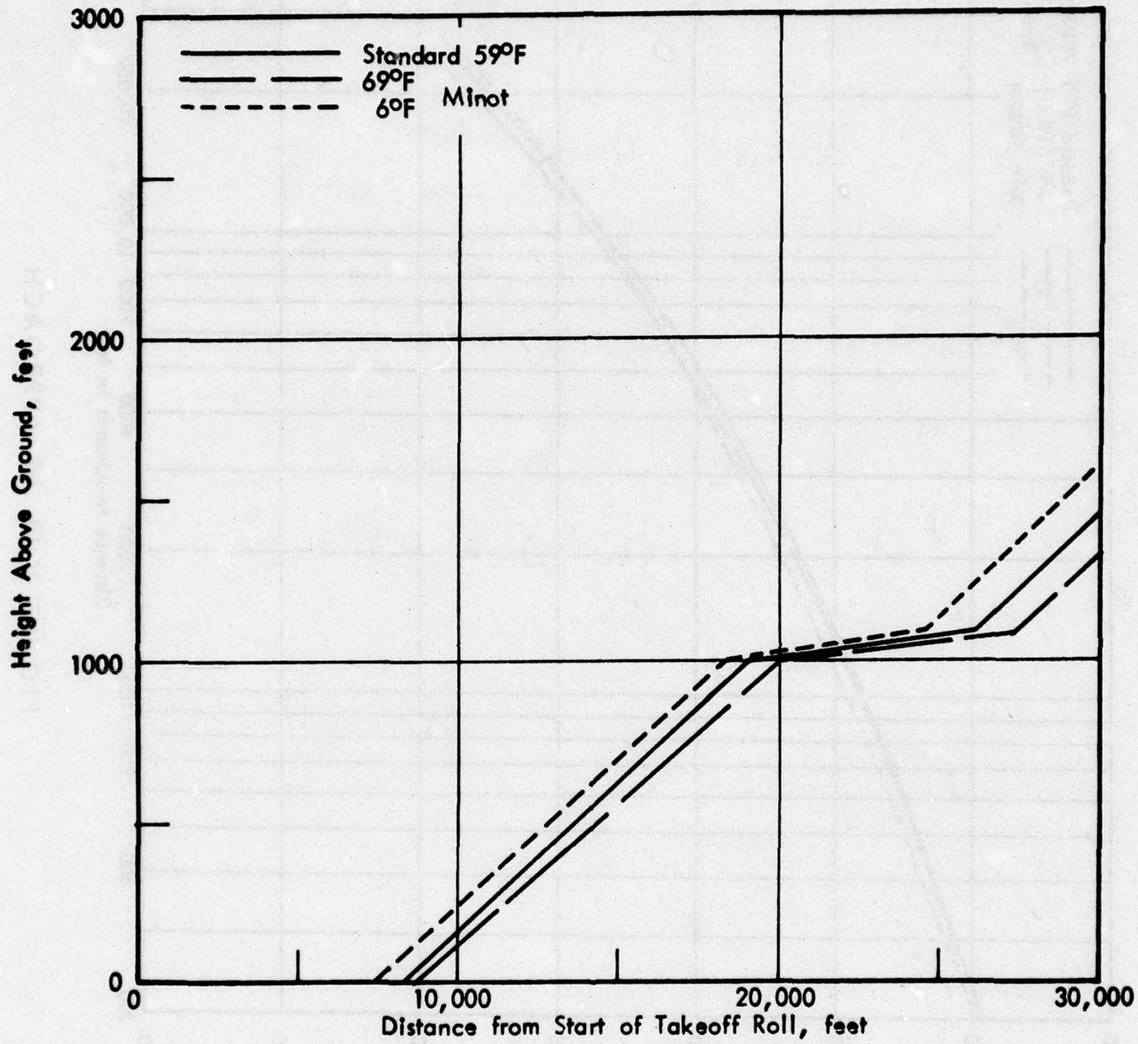

FIGURE V-11 CLIMB PERFORMANCE KC-135A

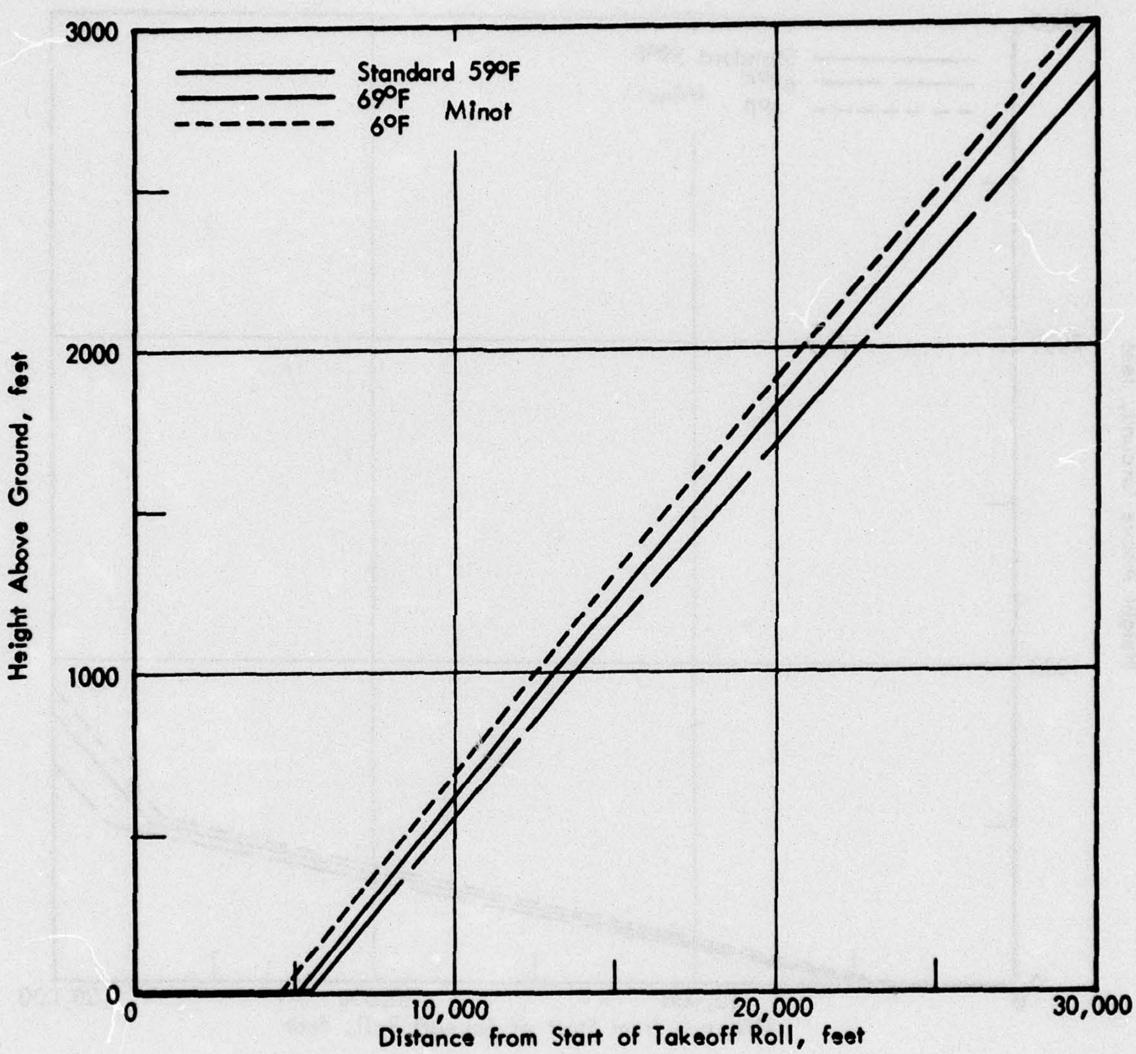

FIGURE V-12 B-52H CLIMB PERFORMANCE

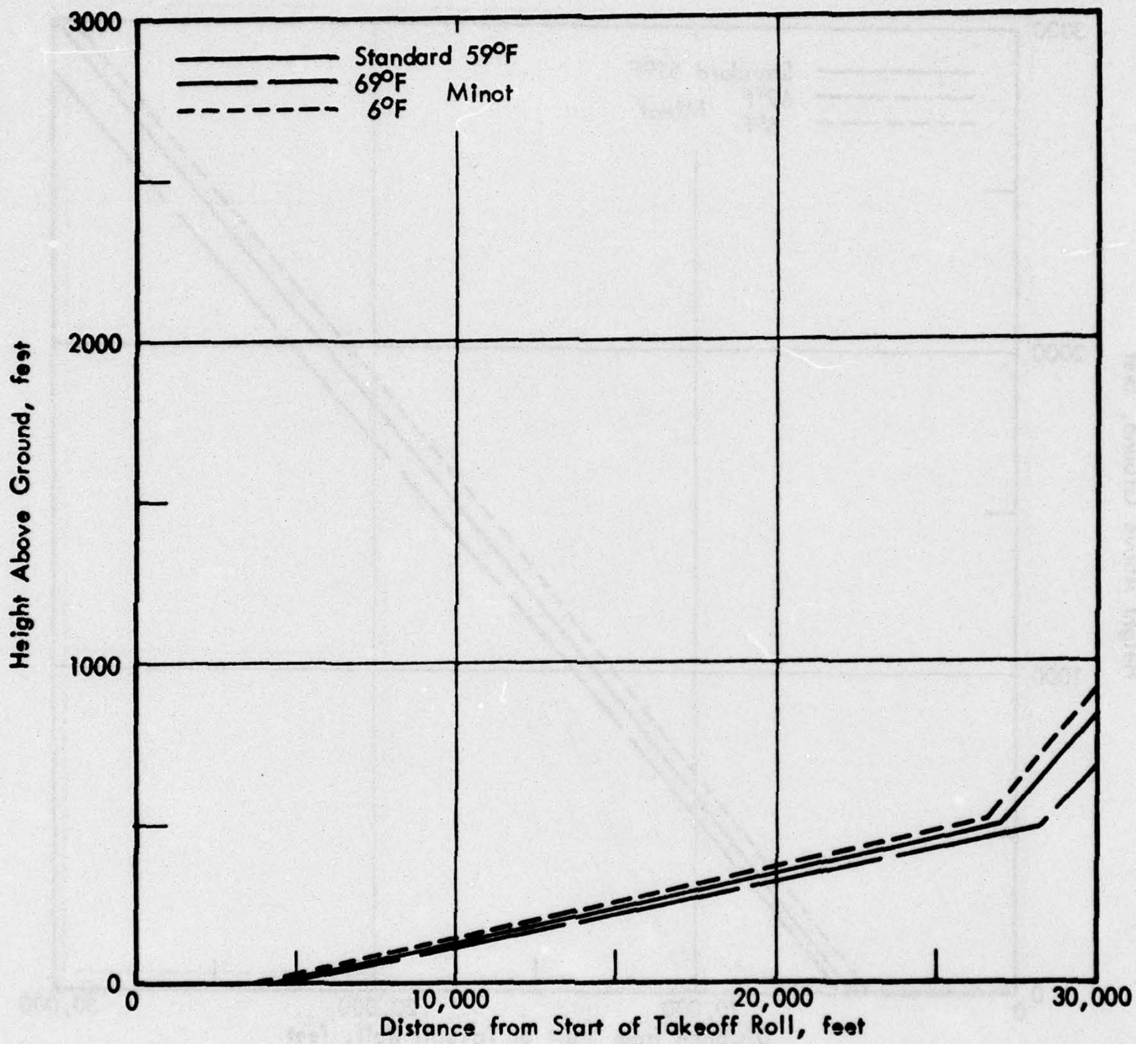

FIGURE V-13 F-106 CLIMB PERFORMANCE

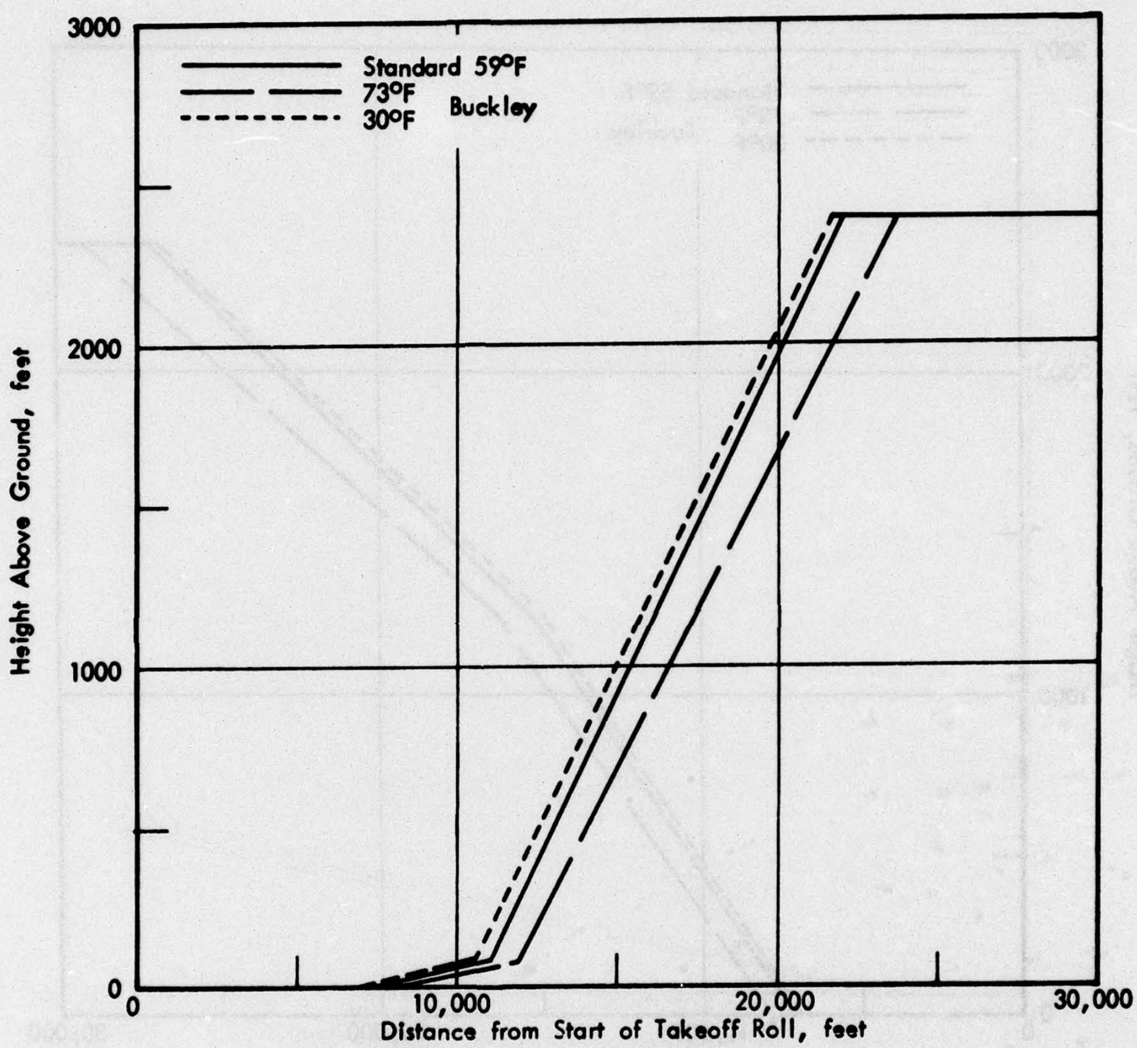

FIGURE V-14 F-100 CLIMB PERFORMANCE

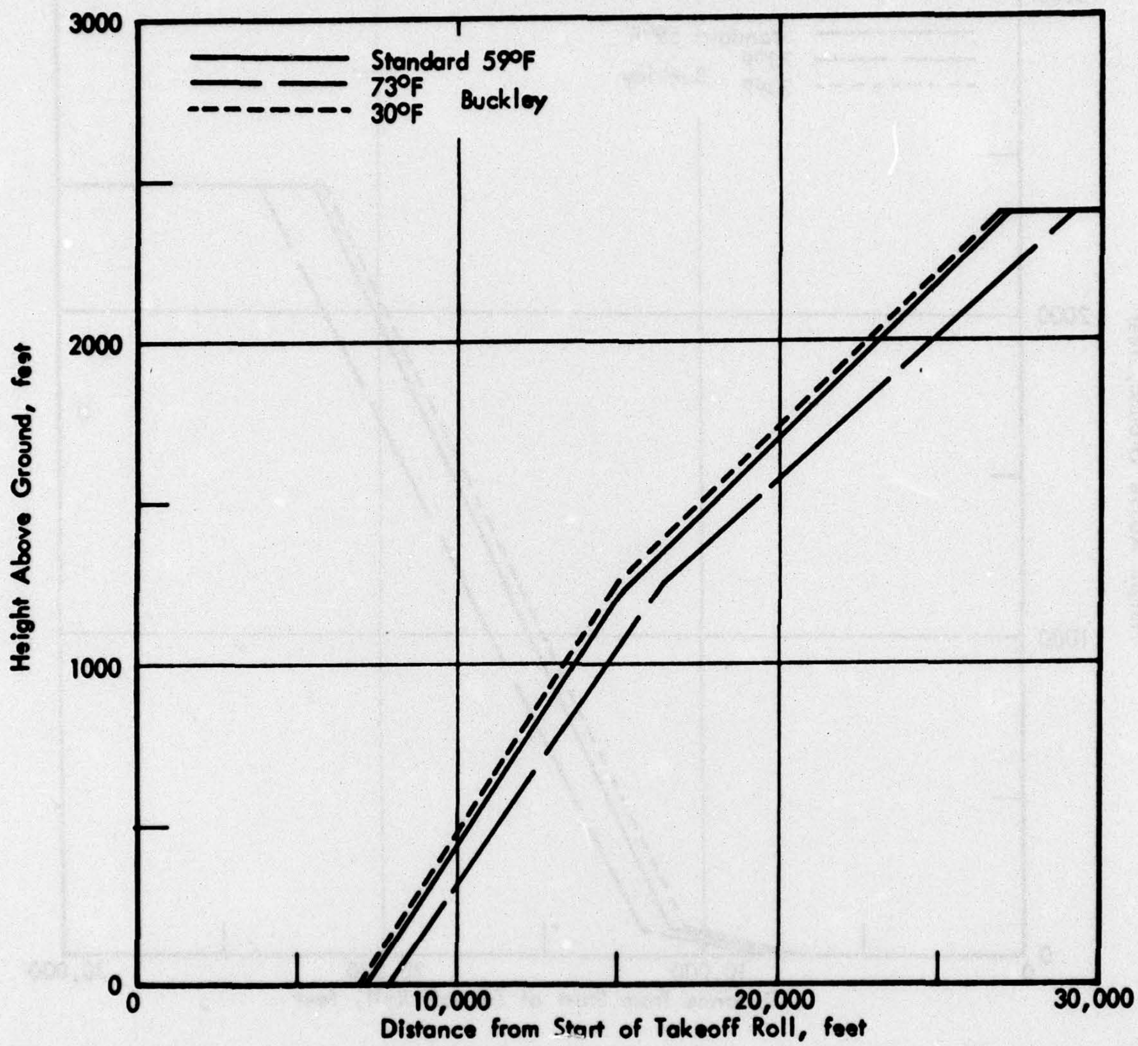

FIGURE V-15 A-7 CLIMB PERFORMANCE

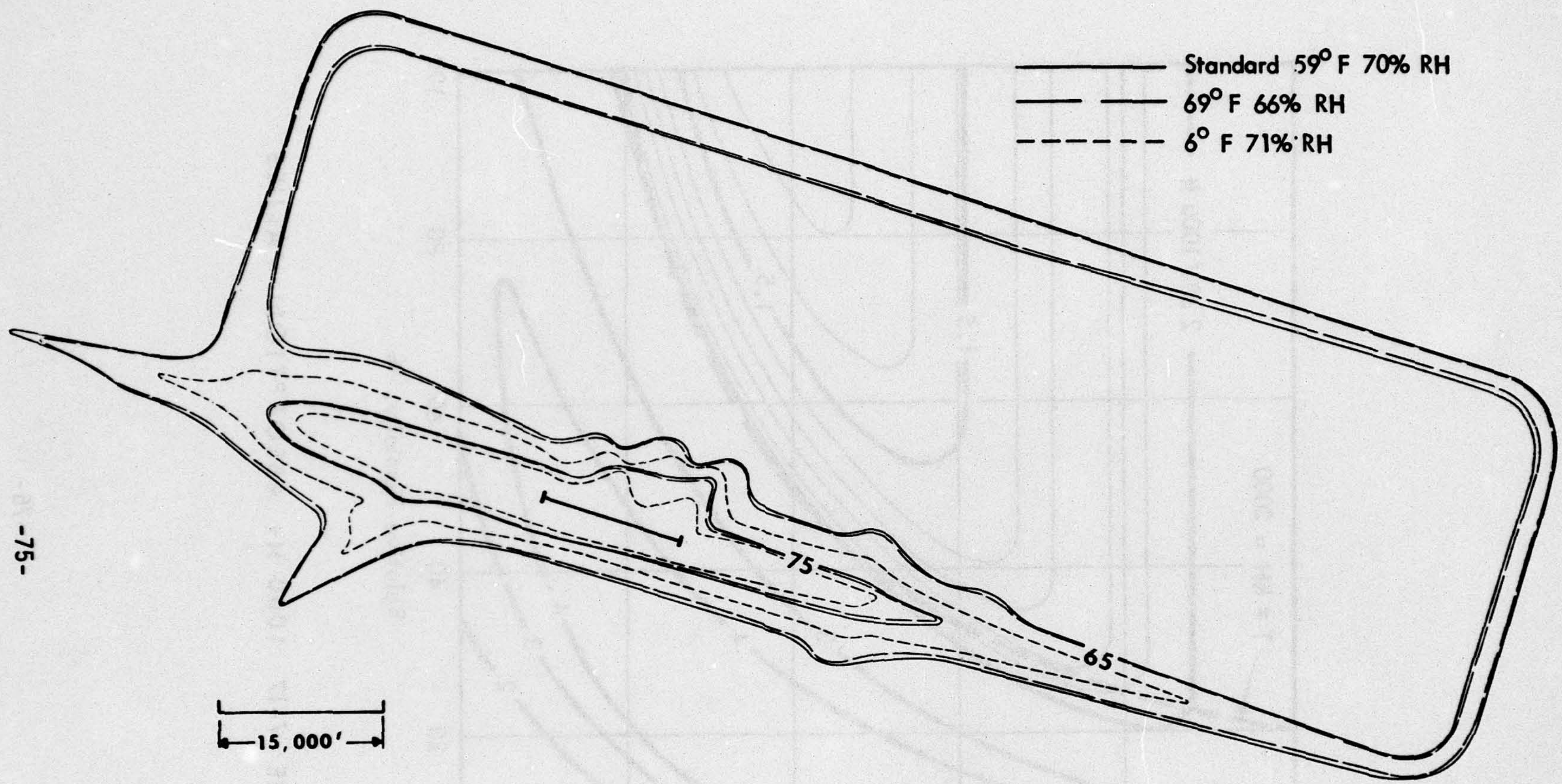

FIGURE V-16. COMPARATIVE DNL CONTOURS FOR MINOT AFB

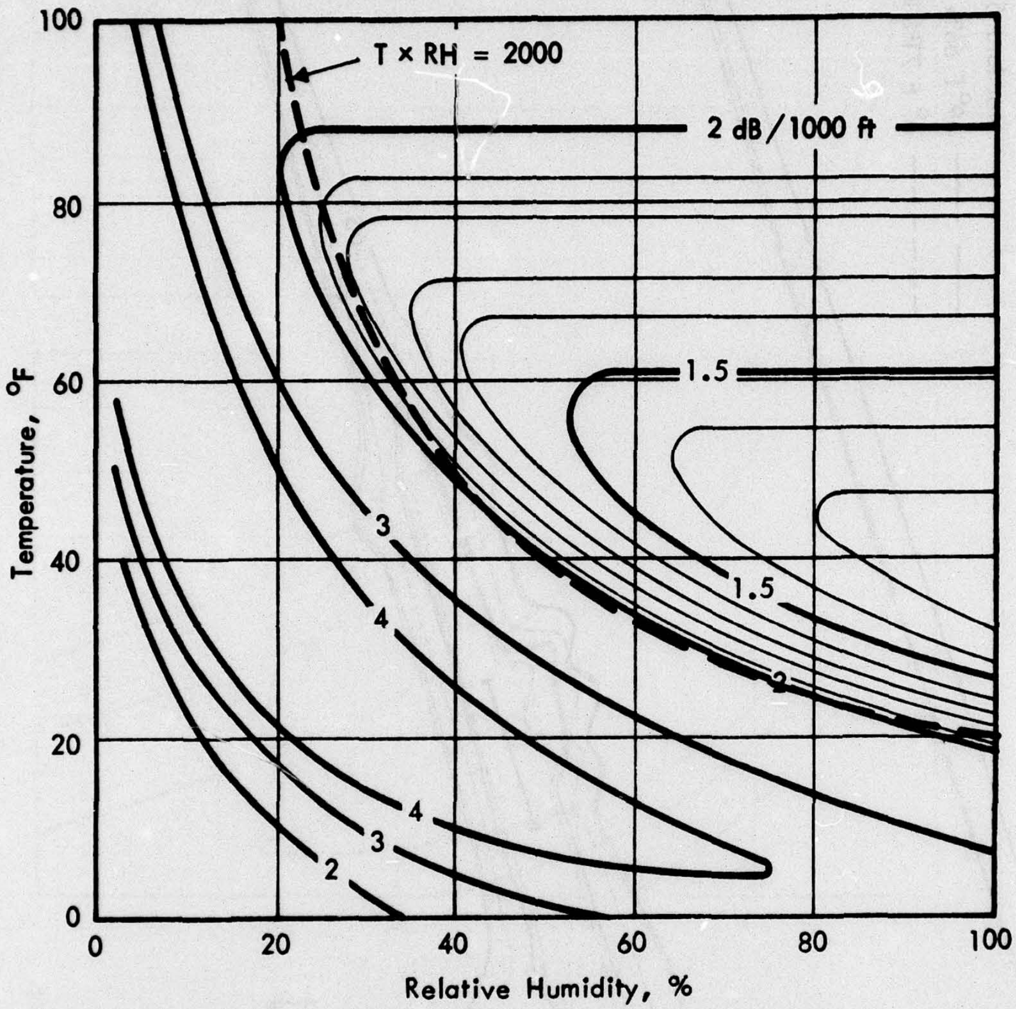

FIGURE V-17 1000 Hz ABSORPTION VALUES

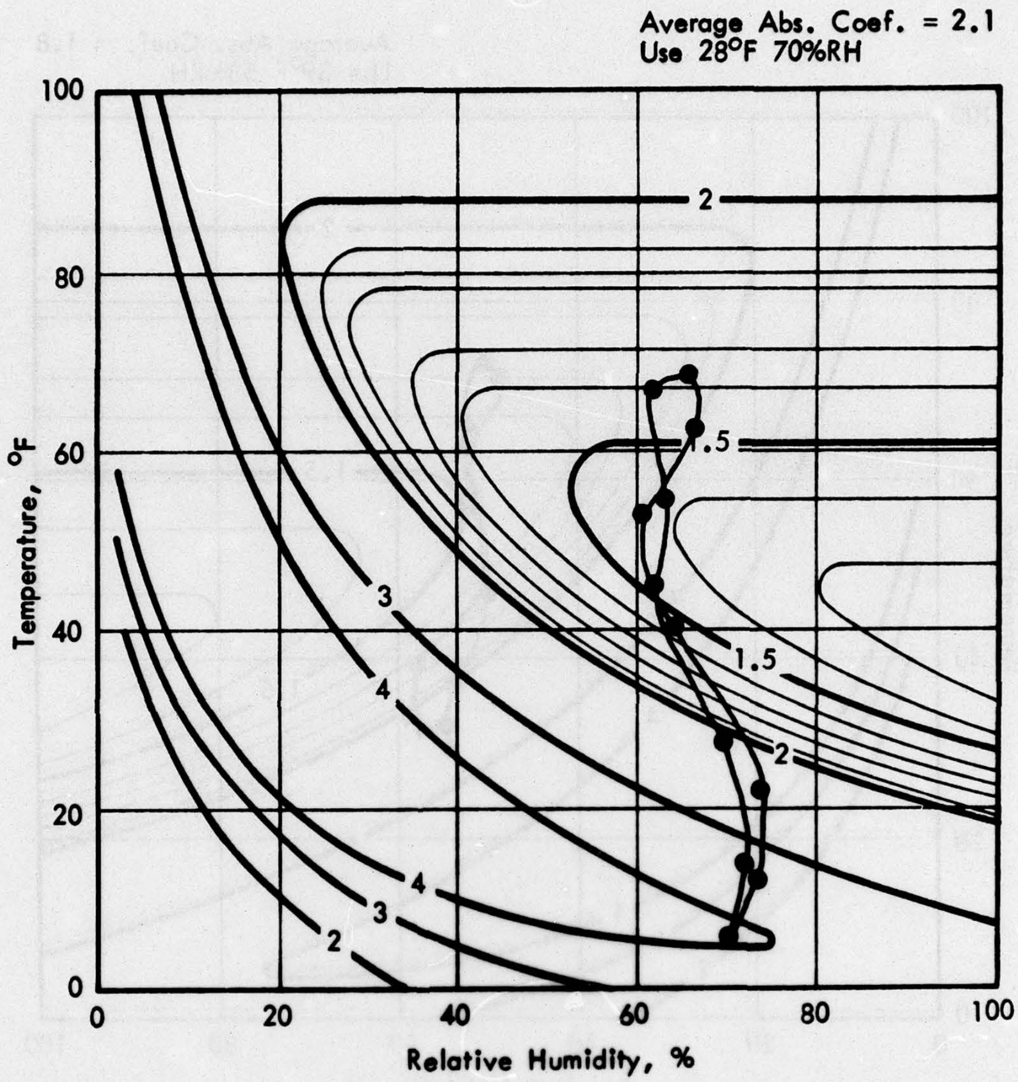

FIGURE V-18 ANNUAL VARIATION OF ABSORPTION AT MINOT AFB

Average Abs. Coef. = 1.8
Use 39°F 58%RH

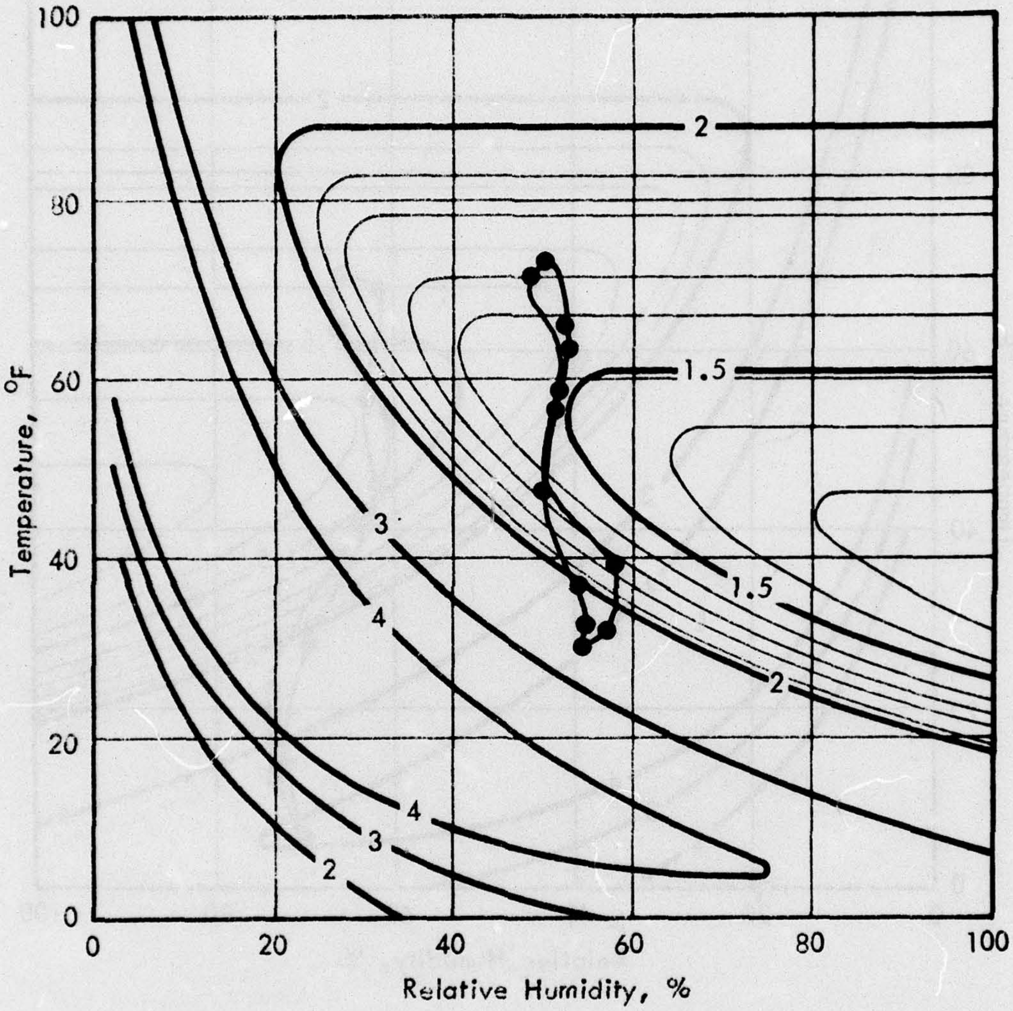

FIGURE V-19 ANNUAL VARIATION OF ABSORPTION AT BUCKLEY ANGB

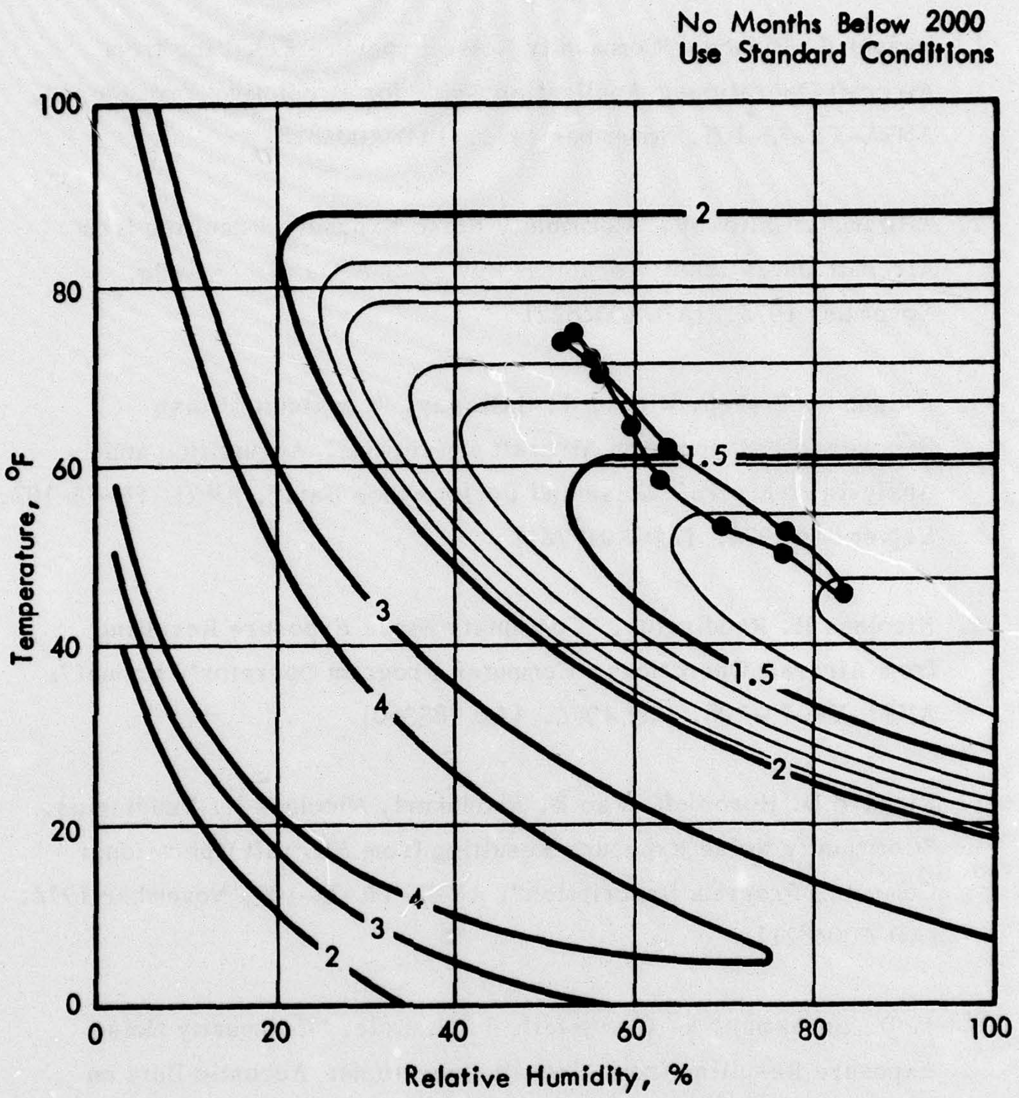

FIGURE V-20 ANNUAL VARIATION OF ABSORPTION AT TRAVIS AFB

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APPENDIX

DNL VERSUS AREA ANALYSIS

To aid in interpreting the significance of the tone correction, the noise exposure values were plotted as a function of exposure area for ten airfields. These graphs for DNL and DNLT, shown in Figures A-1 and A-2 respectively, illustrate the general trend in the data.

There is a fairly constant slope to the curves and for each base, the curves follow the form.

$$DNL = a + b \log (\text{Area}) \qquad \text{(A-1)}$$

This form represents the curves quite accurately although the constants a and b vary from base to base. Table A-1 shows these constants for both DNL and DNLT for the ten bases. This table shows that the slopes of the DNL vs. area and DNLT vs. area curves for each base are virturally identical although the lines have different values for the constant a. The average of the constant b is -15.4 with a standard deviation for the average about 2.5.

Assuming the value of -15.4 for b, Equation A-1 can be used to estimate changes in exposure area given a change in overall exposure level. This method of estimating exposure area change is useful when there is an increase in the number of operations and there is no change in aircraft mix or flight procedures. The equation can also be used to examine the significance of area changes in terms of exposure at a point. For example, a forty percent change in noise exposure area implies that the DNL value has changed by about 2.3 decibels. This corresponds to the magnitude of area

TABLE A-1

LINEAR REGRESSION OF EXPOSURE VERSUS AREA

Regression Lines
(DNL vs. Area)

$$DNL = a + b \log Area$$

$$DNLT = a + b \log Area$$

AIRFIELD	DNL a	DNL b	DNL r^2	DNLT a	DNLT b	DNLT r^2
Charleston	81.537	-11.511	.992	82.885	-11.292	.996
Vance	92.537	-18.971	.999	93.472	-19.285	.999
Seymour-Johnson	91.507	-17.656	.995	92.541	-17.795	.996
Whiteman	76.256	-14.317	.999	77.757	-14.956	.998
McGuire	87.637	-13.437	.999	89.235	-13.608	.999
Minot	88.958	-13.582	.992	90.725	-13.413	.998
Little Rock	85.214	-17.769	.995	85.980	-17.442	.995
Travis	98.892	-16.497	.998	101.470	-17.058	.999
Eglin	90.098	-17.202	.997	90.823	-17.003	.998
Grand Forks	93.257	-12.966	.994	94.942	-13.375	.995

$\bar{a}$ = 68.565 $\bar{b}$ = 15.391 $\bar{a}$ = 89.983 $\bar{b}$ = -15.52

s_a = 6.383 s_b = 2.523 s_a = 6.608 s_b = 2.55

LDN = 88.565 - 15.391 log Area

DNLT = 89.983 - 15.52 log Area

$$\begin{array}{r} 89.983 \\ \underline{-88.565} \\ 1.41\% \end{array}$$

changes at Minot and implies a 2.3 decibel impact due to the tone corrections at this base. On the other hand, a thirteen percent area change would imply a change of about 0.8 decibels. This would correspond to air bases with few tone producing aircraft such as Eglin, Little Rock and Vance.

Another way to put the area change in perspective is to examine the percent area change that results from a five decibel change in exposure level. A five decibel change is of particular interest since this is the interval at which contour areas are currently being plotted. Using Equation A-1, it can be shown that a five decibel change results in a 211 percent change in area.

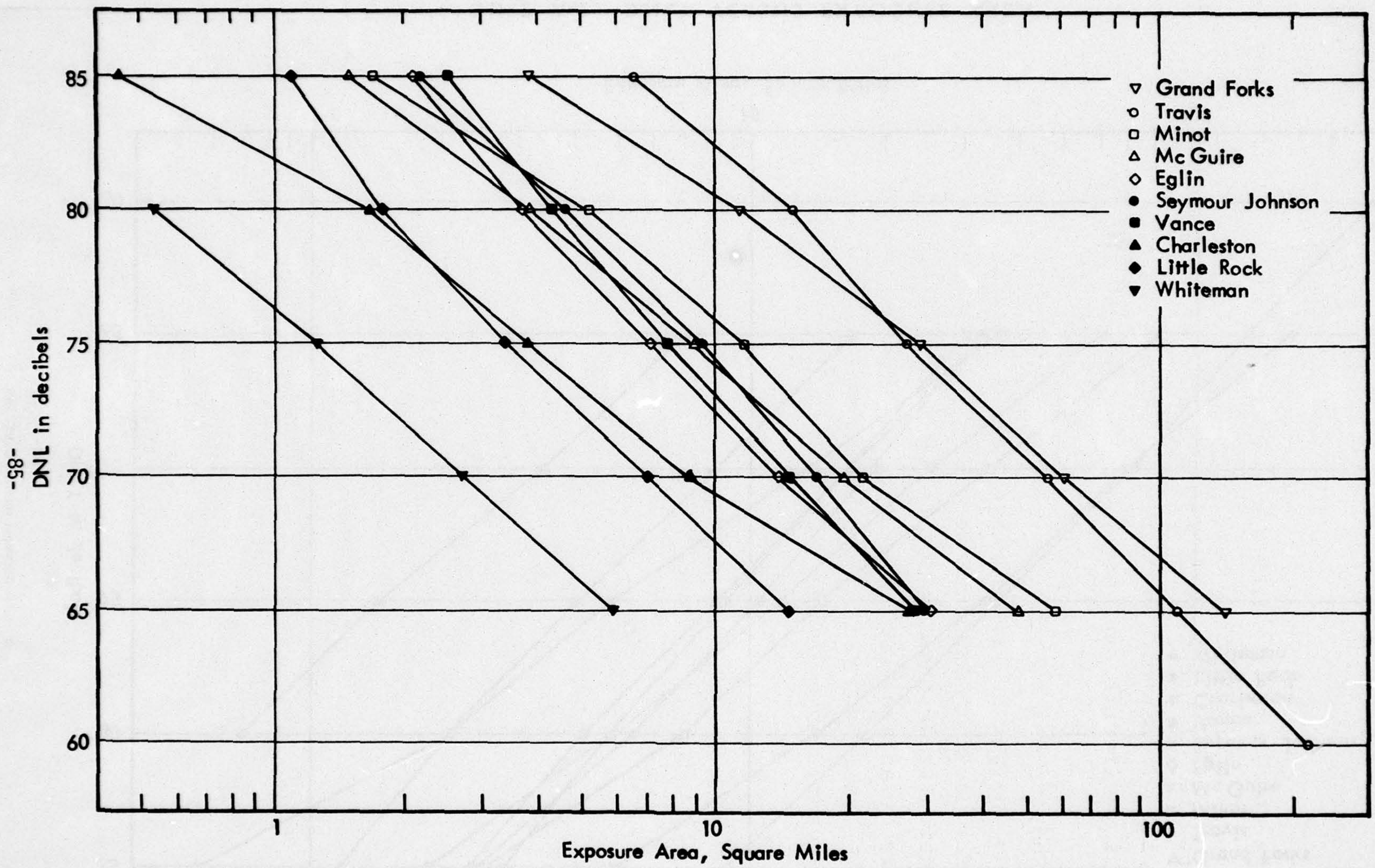

FIGURE A-1 DNL VERSUS EXPOSURE AREA

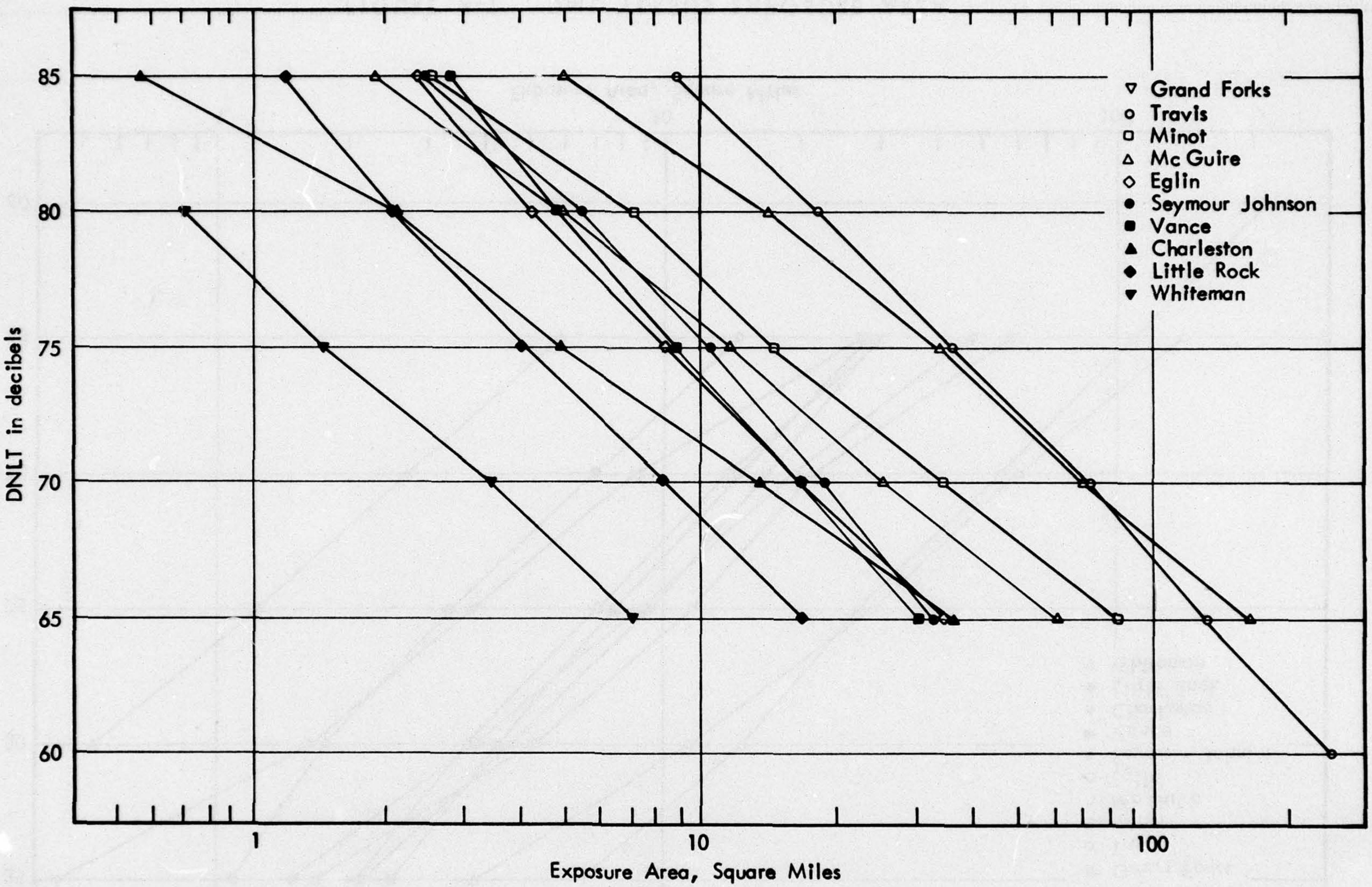

FIGURE A-2 DNLT VERSUS EXPOSURE AREA

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